Safe Flight 21 Master Plan

Version 2.0

April 2000

Safe Flight 21 Steering Group

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Executive Summary

Introduction

Safe Flight 21 is a cooperative government/industry effort to evaluate enhanced capabilities for Free flight based on evolving Communications, Navigation and Surveillance (CNS) technologies. Safe Flight 21 will demonstrate the in-cockpit display of traffic, weather and terrain information for pilots and will provide improved information for controllers. The new technologies on which this program is based include the Global Positioning System (GPS), Automated Dependent Surveillance – Broadcast (ADS-B), Flight Information Services (FIS), Traffic Information Service – Broadcast (TIS-B), and their integration with enhanced pilot and controller information displays. Safe Flight 21 will evaluate the safety, service and procedure improvements these technologies make possible.

The purpose of this Master Plan is to present a Safe Flight 21 plan for incrementally specifying, developing and evaluating the operational enhancements called for in the RTCA Joint Government/Industry Roadmap[†]

The primary objective of the Safe Flight 21 program is to enable and expedite decisions by stakeholders on implementing nine operational enhancements:

1. Weather and Other Information to the Cockpit
2. Cost Effective CFIT Avoidance
3. Improved Terminal Operations in Low Visibility
4. Enhanced See and Avoid
5. Enhanced En Route Air-to-Air Operations
6. Improved Surface Surveillance and Navigation for the Pilot
7. Enhanced Surface Surveillance for the Controller
8. ADS-B Surveillance in Non-Radar Airspace
9. ADS-B Surveillance in Radar Airspace

Government and industry will jointly demonstrate and evaluate these enhancements in an operational environment. In doing these demonstrations and evaluations, the enhancements will be refined. Prior to committing the FAA and the users to a full scale implementation of

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† RTCA Select Committee, Joint Government/Industry Roadmap for Free Flight Operational Enhancements, August, 1998.

these enhancements, there needs to be a consensus of the feasibility and business case for the enhancements among the stakeholders shown in Figure 1.

Another objective of the Safe Flight 21 program is to reduce the risk of implementing the operational enhancements listed above. Certification and obtaining operational approval from the FAA represent significant risks to achieving these enhancements. Thus, the program will have an objective to develop innovative processes to expedite the certification and operational approval of these enhancements when they are shown to be feasible and useful to the stakeholders.

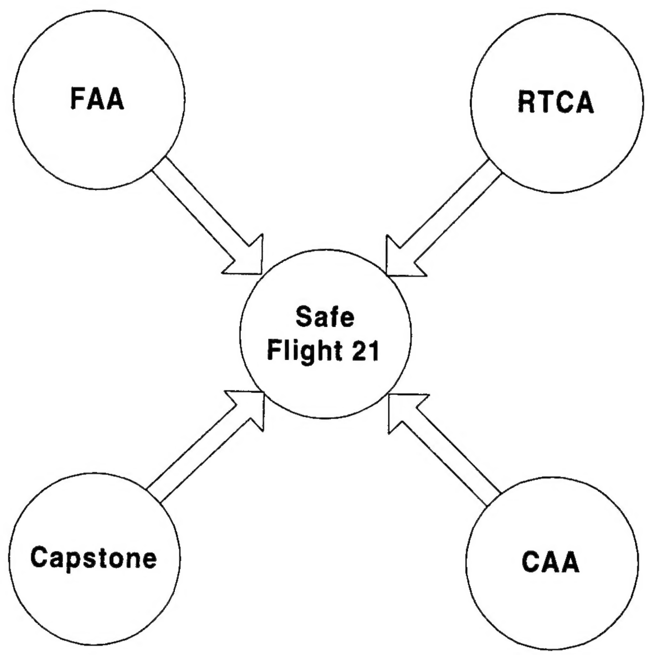

Figure 1. Government/Industry Safe Flight 21 Program

A first step toward developing and evaluating these nine high-level enhancements is to clarify the specifics of what they include and develop top-level details of the operations involved and the systems required. The Safe Flight 21 Steering Group has taken this step and defined the scope of Safe Flight21 in terms of specific applications (within the enhancements) that will be developed and evaluated. The applications within each enhancement are listed in Table 1. These applications are described in more detail in the Master Plan.

Table 1. Safe Flight 21 Enhancements and Applications

Enhancement		Opeval Fiscal Year	Application
Weather and Other Information to the Cockpit	1.1.1	00 (AK)	Initial FIS-B based on today's availability (NEXRAD graphics, METAR/SPECI, TAFs, SIGMETs, PIREPs and sever weather forecast alerts)
	1.1.2	01 (AK)	Add products such as NOTAMs, lightning, icing, turbulence, real time SUA, and Volcanic ash
Cost Effective CFIT Avoidance	2.1	00 (AK)	Low cost terrain situational awareness
	2.2	01 (AK)	Increased access to terrain constrained low altitude airspace
Improved Terminal Operations in Low Visibility	3.1.1	99 (ORV)	Enhanced visual approaches (Visual acquisition with existing procedures, ADS-B only)
	3.1.2	00 (ORV)	Enhanced visual approaches (with new procedures using ADS-B only)
	3.1.3	01 (ORV)	Enhanced visual approaches (with new procedures using ADS-B and TIS-B)
	3.2.1	00 (ORV)	Approach spacing (for visual approaches)
	3.2.2	01 (ORV)	Approach spacing (for instrument approaches)
	3.3		Enhanced parallel approaches in VMC/MVMC
	3.4	00 (ORV)	Departure spacing/clearance (VMC in radar)
	3.5		Approaches to closely space parallel runways
Enhanced See and Avoid	4.1.1	99 (ORV)	Enhanced visual acquisition of other traffic for see-and-avoid (using ADS-B only)
	4.1.2	01 (Both)	Enhanced visual acquisition of other traffic for see-and-avoid (ADS-B and TIS-B)
	4.2.1	00 (ORV)	Conflict detection
	4.2.2	02 (ORV)	Conflict resolution
Enhanced En Route Air-to-Air Operations	5.1		Closer climb and descent in non-radar airspace
	5.2.1	00 (AK)	Pilot situational awareness beyond visual range
	5.2.2		Delegated air-to-air self-separation for one-in-one-out airspace
	5.3		In-trail spacing in en route airspace
	5.4		Merging in en route airspace
	5.5		Passing maneuvers in en route airspace
Improved Surface Surveillance and Navigation for the Pilot	6.1.1	00 (Both)	Runway and final approach occupancy awareness (using ADS-B only)
	6.1.2	01 (ORV)	Runway and final approach occupancy awareness (using ADS-B and TIS-B)
	6.2	01 (Both)	Airport surface situational awareness
	6.3		Enhanced IMC airport surface operations
Enhanced Surface Surveillance for Controller	7.1	00 (ORV)	Enhance existing surface surveillance with ADS-B
	7.2	01 (ORV)	Surveillance coverage at airports without existing surface surveillance
ADS-B Surveillance in Non-Radar Airspace	8.1	00 (AK)	Center situational awareness with ADS-B
	8.2	00 (AK)	Radar-like services with ADS-B
	8.3	00 (AK)	Tower situational awareness beyond visual range
Establish ADS-B Separation Standards	9.1.1	00 (Both)	Radar augmentation with ADS-B to support mixed equipage in terminal airspace
	9.1.2		Radar augmentation with ADS-B to achieve existing separation standards in terminal airspace
	9.2.1	00 (Both)	Radar augmentation with ADS-B to support mixed equipage in en route airspace
	9.2.2		Radar augmentation with ADS-B to achieve existing separation standards in en route airspace
	9.3		Reduced separation standards with ADS-B

Applications that will not be evaluated between 1999 and 2002

Safe Flight 21 Structures, Roles and Responsibilities

The structure for coordinating Safe Flight 21 as a whole is shown in Figure 2. The RTCA's Free Flight Steering Committee is the focus of industry and industry-FAA consensus on the new CNS capabilities. Through the Free Flight Select Committee the enhancements for Safe Flight 21 were defined and their development and evaluation will be monitored. The Safe Flight 21 Steering Group is the focus of ongoing coordination between stakeholders and the FAA's Safe Flight 21 program. The FAA participates in each of these levels. The FAA product lead for Safe Flight 21 co-chairs the Safe Flight 21 Steering Group,

Responsibilities for elements of Safe Flight 21 are allocated to (or shared between) FAA and industry as appropriate. There are three subgroups under the Safe Flight 21 Steering Group that address these issues: the Operations/Procedures subgroup, the Cost/Benefit subgroup, and the Technical/Certification subgroup. The roles for the steering committee and these subgroups have been defined in the Safe Flight 21 Steering Group Terms of Reference. These subgroups are co-chaired by representatives from the FAA's Air Traffic, Aircraft Certification, and Systems Engineering organizations.

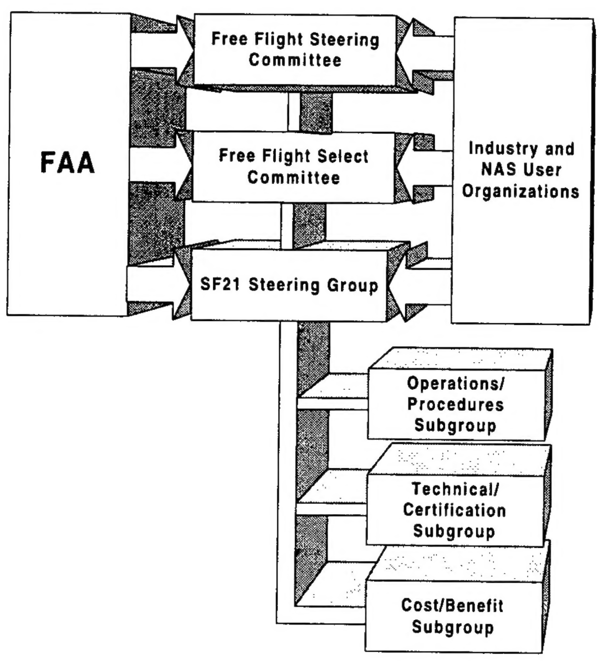

Figure 2. Safe Flight 21 Steering Group Organization

Safe Flight 21 Steering Group

- Provides on-going guidance on the scope, priority, and schedule of evaluation activities for the nine operational enhancements.
- Oversees the objective assessment of candidate ADS-B technologies. The assessment will identify the capability, cost and ability of each technology to satisfy the requirements of the operational capabilities identified in the Safe Flight 21 Roadmap.
- Establishes metrics to be used in the evaluation of operational benefits and the assessment of costs.
- Analyzes the cost and benefit of the nine operational enhancements and makes recommendations to the Free Flight Select Committee on which enhancements or combination of enhancements yield the greatest return on investment in terms of safety, efficiency, capacity and human productivity.
- Should changes in the roadmap become necessary, the Safe Flight 21 Steering Group will present specific recommendations and rationale to the Free Flight Select Committee for action.

Operations and Procedures Subgroup

The operations and procedures subgroup is responsible for leading and coordinating the Safe Flight 21 detailed application description development for each of the Safe Flight 21 applications and will also provide guidance and oversight of procedures development for each of the evaluations in the Ohio Valley with the Cargo Airline Association (CAA) and in Alaska with the Capstone initiatives. The subgroup will ensure that pilot, controller, operator, FAA air traffic management and flight standards issues are addressed. The group will also coordinate with RTCA SC-186, 193 and 195 and the FAA Integrated Requirements Team as appropriate. The group will work with the Technical/Certification subgroup to define how each of the technologies is used to gain a beneficial capability. Those definitions will be used as the basis for certification criteria.

Technology and Certification Subgroup

The Technology and Certification subgroup will oversee the ADS-B system link alternatives evaluation, define high-level system requirements (ground station/avionics), and coordinate requirements for equipment certification and operational approvals necessary for operational evaluations and ultimately NAS-wide implementation. The subgroup will assist the Cost/Benefit subgroup with defining avionics and group system costs, and will work with the Operations/Procedures

subgroup to define the intended function of each technology as a basis for certification.

Cost/Benefit Subgroup

The Cost/Benefit subgroup will collaborate with the other Safe Flight 21 subgroups, FAA System Engineering, manufacturers and the operators to obtain cost and benefit data and work with the FAA on a cost/benefit analysis. The analysis will provide information on the trade-off between the differing levels of capability and different architecture and technology options that are explored within Safe Flight 21. This analysis will serve as the basis for recommendations to the Safe Flight 21 Steering Group. Initial focus will be placed on assessing the cost and benefits of the three candidate ADS-B/FIS links as they pertain to the nine operational enhancements. The Cost/Benefit subgroup will collaborate with the Technical/Certification subgroup and manufacturers to define the costs of link alternatives and with the Operations/Procedures subgroup to quantify and qualify economic and safety benefits derived from each capability and their integration.

The Safe Flight 21 evaluations are being conducted in the Ohio Valley and in Alaska. The Ohio Valley evaluation is built on stakeholder participation in the planning and conduct of the evaluations. The organizational structure of the Ohio Valley effort is shown in Figure 3. In this structure the stakeholders form a steering committee to ensure that their interests in the evaluation are addressed. The day-to-day activities of the planning and execution of the evaluation are managed by the Operational Evaluation Coordination Group (OCG). Beneath the OCG are subgroups that plan the various aspects of the evaluation.

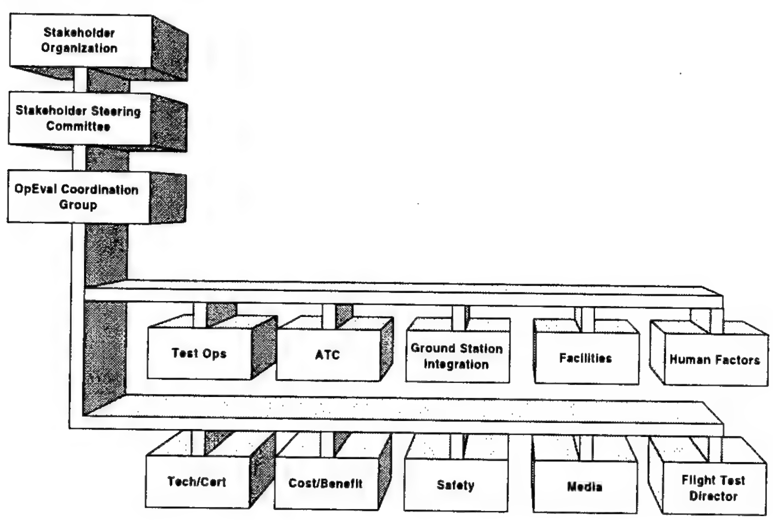

Figure 3. Ohio Valley Operational Evaluation Organization

In Alaska the FAA-managed Capstone Program is the focal point of the evaluations. The organizational structure of this effort is shown in Figure 4. The Capstone Program Office is staffed and supported through temporary assignments by the Alaskan Region line organizations and the Regional Administrator's staff. Each line organizational representative is responsible to develop individual detailed work plans for each aspect of the program to which they are the lead. Staffing includes program support personnel, headquarters liaisons, and representatives from regional Flight Standards, Air Traffic, Airway Facilities, NAS Implementation, Aircraft Certification, logistics and Aviation System Standards organizations. The Capstone VFR-to-IFR Test and Evaluation Master Plan (TEMP) is produced by the Capstone Operations Group (COG), formed by the Capstone Program Office. It presents program background, system descriptions, required resources and test management, organization, and planning activities that will be active in evaluating the use of ADS-B to provice radar-like service in Bethel, AK. The membership of the COG will also be in place to evaluate other applications as desired.

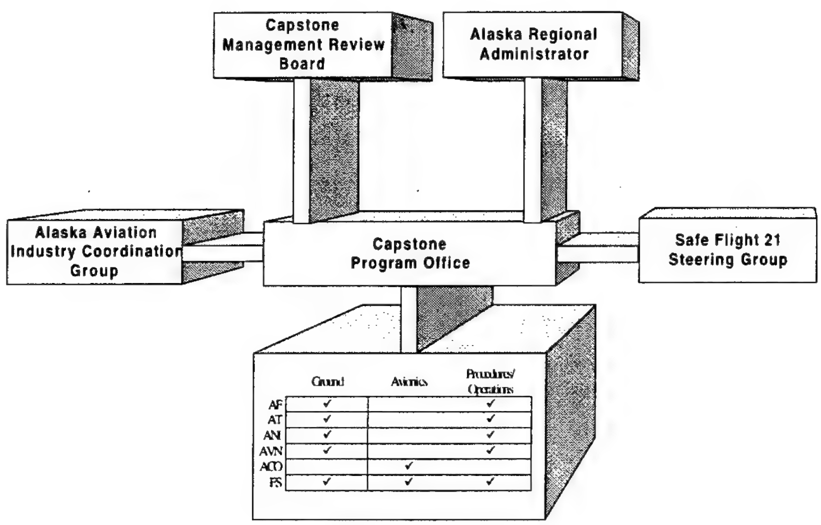

Figure 4. Capstone Operational Evaluation Organization

Safe Flight 21 Information Flows and Transition to Implementation

The activities and progress of Safe Flight 21 is based on stakeholder consensus. Therefore, the informational flow and decision making of this program is designed to involve the stakeholders. As depicted in Figure 5, the RTCA *Roadmap*, other RTCA documents and the NAS Architecture are the main drivers of Safe Flight 21 activities. This document (the Safe Flight 21 Master Plan) uses the material in the *Roadmap*, the MASPS and the

architecture to define the sequence of applications to be investigated. The control of this document is shared between the FAA and the RTCA Safe Flight 21 Steering Group.

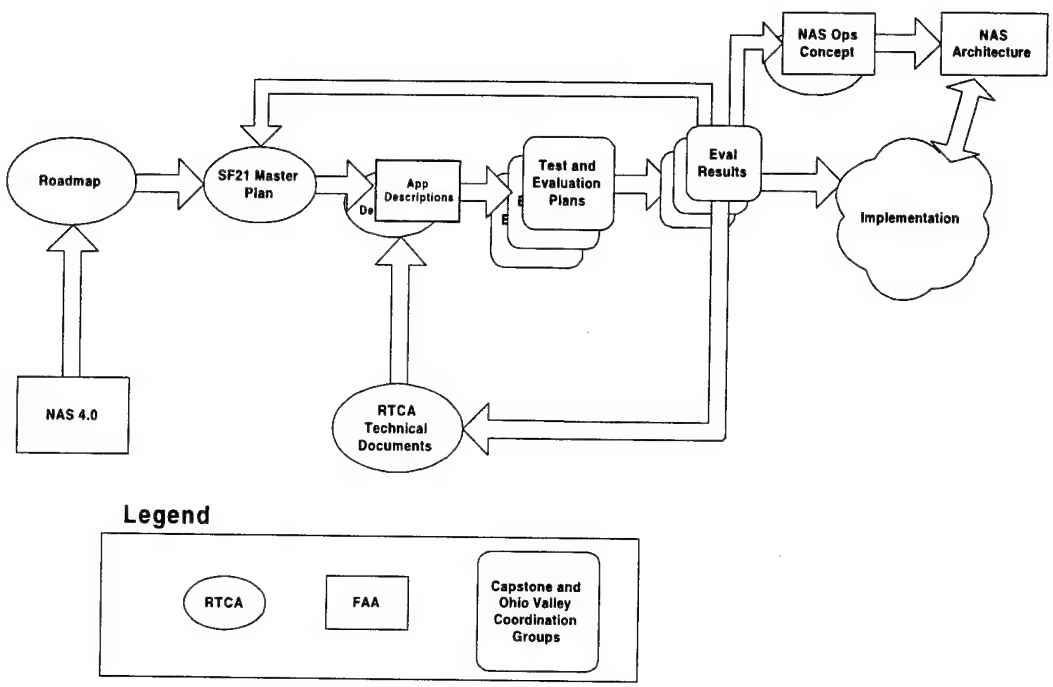

Figure 5. Safe Flight 21 On-Going Information Flows

For each Operational Evaluation there will be a Test and Evaluation Master Plan. The control of this document will be shared between the Safe Flight 21 program office and the OpEval Coordination Group for the particular OpEval.

Out of each Operational Evaluation will come a set of results. These results include data, analyses of that data, and any consensus on what the operational capabilities should be and their benefits. This information is then fed back into the Master Plan and fed forward into the system Operational Concept. These validated, stakeholder embraced operational concepts will recommend (or identify corrections to) planned FAA and stakeholder architectures.

In coordination with the aviation community, the FAA is defining a strategy for phased implementation of Safe Flight 21 capabilities which prove to be beneficial and cost effective. This is summarized in Figure 6 which illustrates three levels within this continuum with examples of possible capabilities at each level.

FAA strategy in this regard is to encourage voluntary avionics equipage by supporting early highly-beneficial capabilities. One aspect of this is early selection of a long-term link

decision for ADS-B which is a prerequisite for implementation beyond Safe Flight 21. Another aspect is deployment of supporting infrastructure where it is sufficiently cost-beneficial to do so. (See Figure 7)

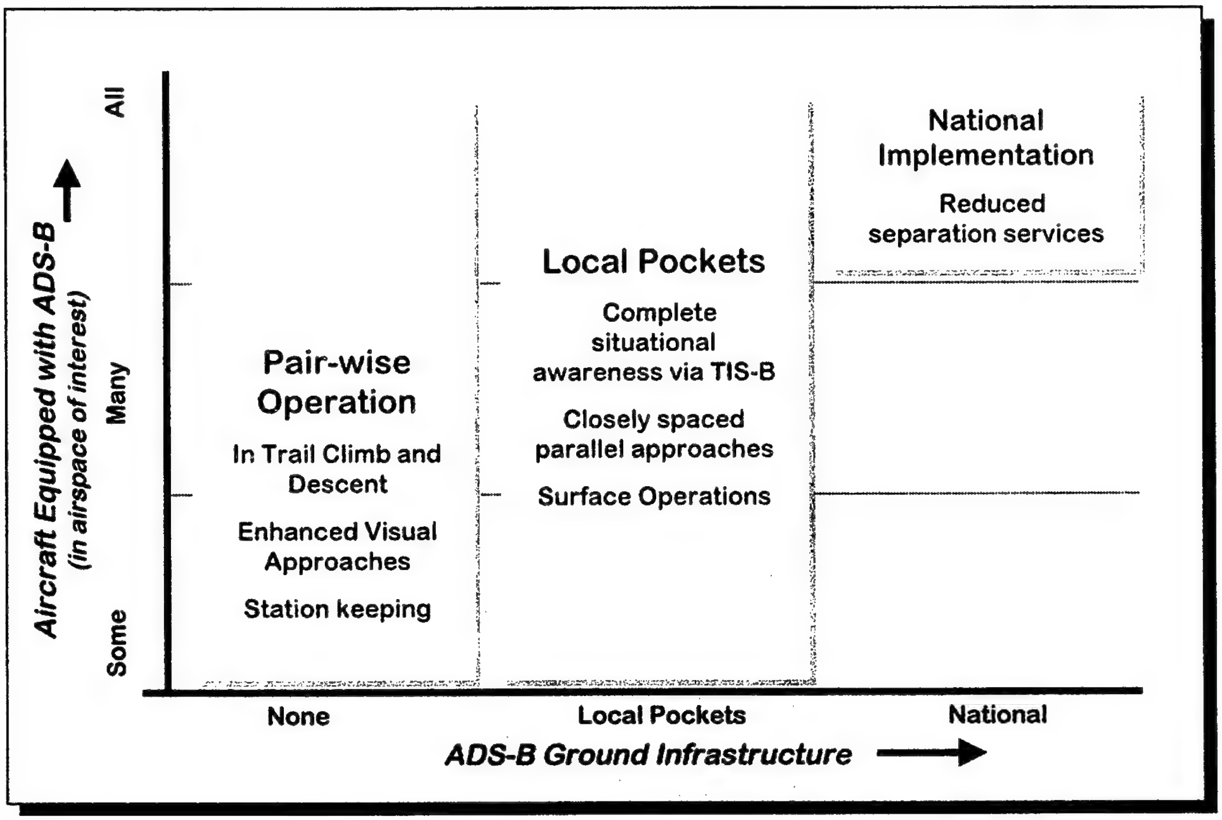

Figure 6. ADS-B Equipage and Transition Profile

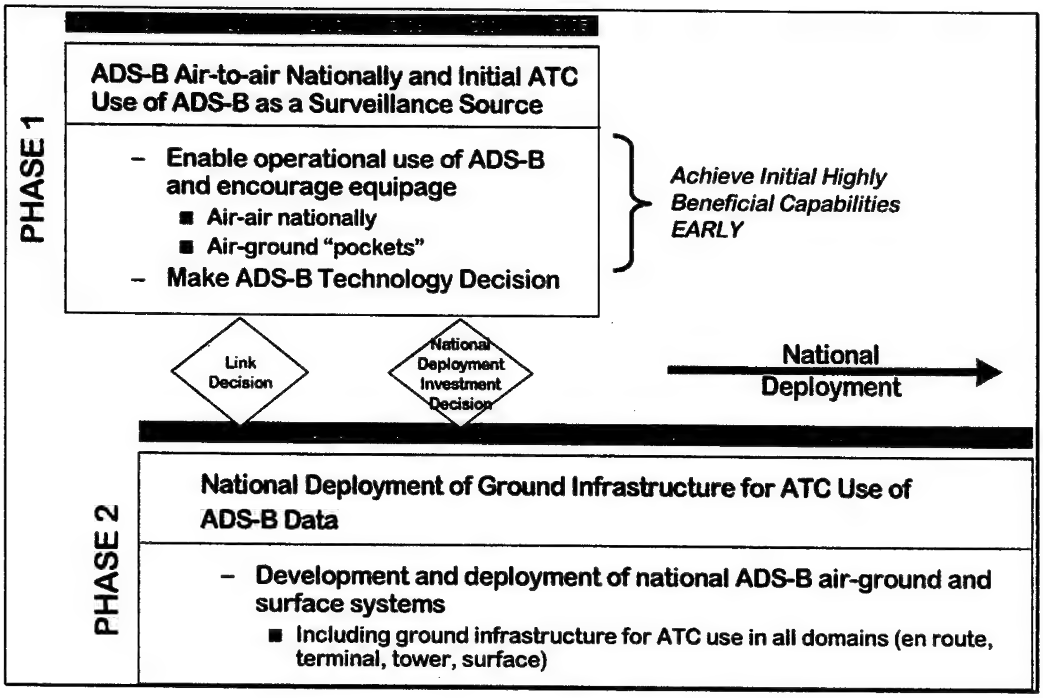

Figure 7. ADS-B Implementation Phases

The FAA realized that many new technology research and implementation efforts do not fit the normal acquisition program mold and developed a process that would allow for tailoring the AMS on a case-by-case basis. Figure 8 summarizes the flow of a research effort from establishing a need through acquisition and implementation. There are three logical decision points in this process where the FAA will review the data generated by the evaluation and cost benefit analysis for a given research effort and determine the next steps to be taken to move the technology towards implementation.

The process for decision-making and implementation has been embraced by the Safe Flight 21 program and it is expected that the decision and review process will be different for different applications. A primary determinant will be the nature and level of ground infrastructure required. The FAA has defined three paths toward implementation for applications and locations that differ in this way. These paths are shown in Figure 9 which builds off of the generic research effort flow chart shown in Figure 8. The upper path corresponds to applications based primarily on avionics used aircraft-to-aircraft without significant ground infrastructure. The lower path corresponds to limited implementations of infrastructure in geographic pockets where user equipage and benefits justify early usage. The central path corresponds to the standard FAA Acquisition Management System (AMS) for large-scale acquisitions and modernization.

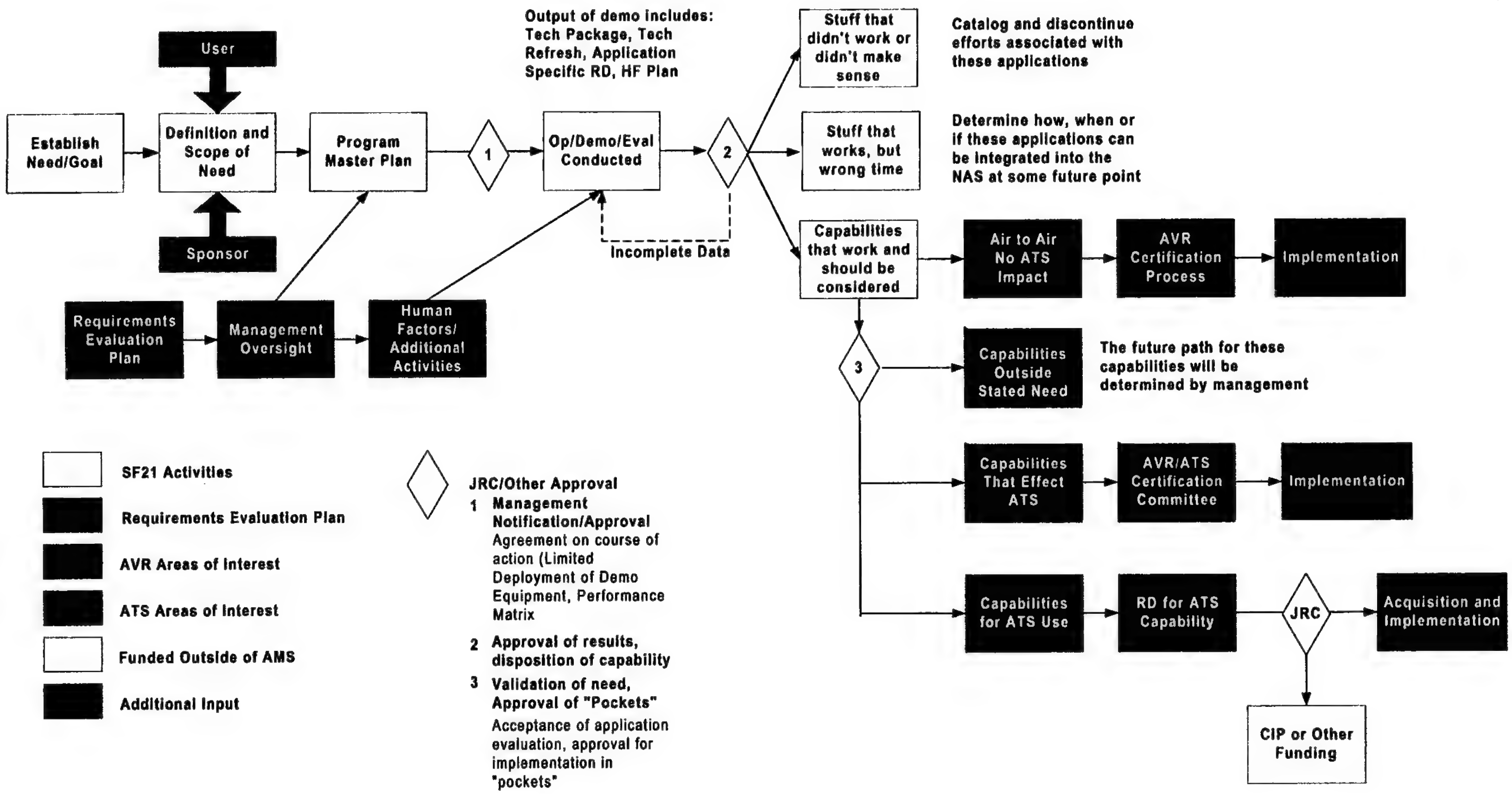

Figure 8. Research Efforts and the AMS Process

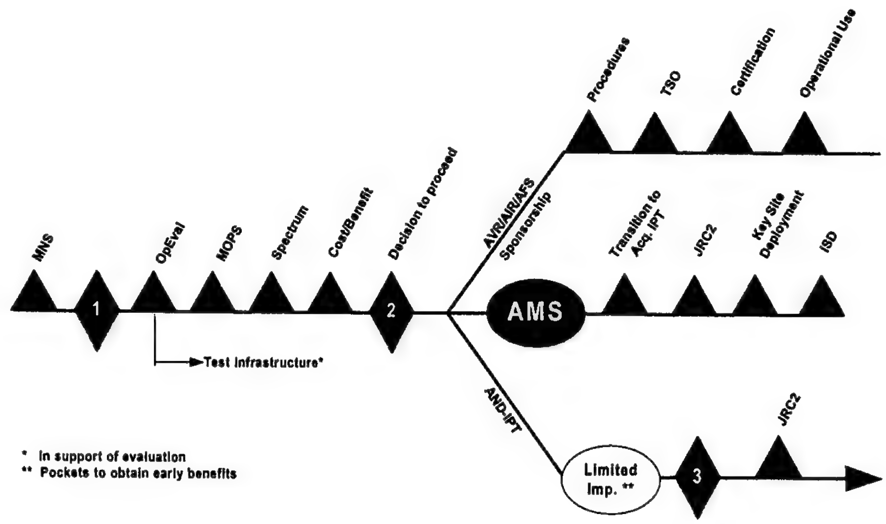

Figure 9. Safe Flight 21 Application Implementation Process

Safe Flight 21 Target Schedule

The Safe Flight 21 Steering Group, in coordination with participating stakeholders and other, has adopted a target schedule for evaluating and implementing the Safe Flight 21 applications within the nine operational enhancements. In each case, applications must progress from initial definition and development through an evaluation process that addresses feasibility, acceptability, and business case, into the stakeholder-driven stages of implementation.

This overall target schedule, organized by enhancements and applications, is shown in Figure 10 with the timeline at the right color-coded into Development, Evaluation and Implementation stages. In terms of the tasks described in this plan, the **Define & Development** stage includes Operational Concept, Initial go-ahead base on maturity, Operational Procedures, Human Factors Issues, End to End Performance and Technical Requirements, Interoperability Requirements, and Initial Avionics and Ground Systems. The **Evaluation** stage includes Analysis of Benefits and Constraints, Operational Safety Assessment, and Operational Test and Evaluation. The **Implementation** stage includes Equipment Certification), Operational Approval (which may have been completed earlier but will be complete by the first year), and Implementation Transition.

Figure 10 represents the target schedule established in 1999 by the Safe Flight 21 Steering Group. An update based on more detailed planning and on progress to date is shown in Figure 11.

Target Schedule for SafeFlight 21 Applications

Define & Develop | Evaluate | Implement

#	Name (with development phase if needed)	Location	OpEval Year	Importance low 0 - 10 high	1999	2000	2001	2002	Beyond
1	**Weather and Other Information to the Cockpit**								
1.1.1	wx alerts)	AK	2000	9					
1.1.2	products)	AK	2001	9					
2	**Cost Effective CFIT Avoidance**								
2.1	Low cost terrain situational awareness	AK	2000	10					
2.2	Increased access to terrain constrained low altitude airspace	AK	2001	9					
3	**Improved Terminal Operations in Low Visibility**								
3.1.1	Enhanced visual approaches (exisiting procedures using ADS-B only)	ORV	1999	9					
3.1.2	Enhanced visual approaches (new procedures using ADS-B only)	ORV	2000	9					
3.1.3	Enhanced visual approaches (new procedures using ADS-B and TIS-B)	ORV	2000	6					
3.2.1	Approach spacing (visual approaches)	ORV	2000	9					
3.2.2	Approach spacing (instrument approaches)	ORV	2001	9					
3.4	Departure spacing/clearance (VMC in radar)	ORV	2000						
4	**Enhanced See and Avoid**								
4.1.1	Enhanced visual acquisition see-and-avoid (using ADS-B only)	ORV>AK	1999	7 / 9					
4.1.2	Enhanced visual acquisition see-and-avoid (using ADS-B and TIS-B)	ORV<AK	2001	6 / 9					
4.2.1	Conflict detection	ORV>AK	2000	10 / 8					
4.2.2	Conflict resolution	ORV	2002	10					
5	**Enhanced En Route Air-to-Air Operations**								
5.2.1	Pilot situational awareness beyond visual range	AK	2000	9					
6	**Improved Surface Surveillance and Navigation for the Pilot**								
6.1.1	Runway and final approach occupancy awareness (ADS-B only)	ORV>AK	2000	8					
6.1.2	Runway and final approach occupancy awareness (ADS-B and TIS-B)	ORV	2001	6					
6.2	Airport surface situational awareness	ORV>AK	2001	8					
7	**Enhanced Surface Surveillance for the Controller**								
7.1	Enhance exisiting surface surveillance with ADS-B	ORV	2000	8					
7.2	Surveillance coverage at airports without existing surface surveillance	ORV	2001	8					
8	**ADS-B Surveillance in Non-Radar Airspace**								
8.1	Center situational awareness with ADS-B	AK	2000	9					
8.2	Tower situational awareness beyond visual range	AK	2000	9					
8.3	Radar-like services with ADS-B	AK	2000	8					
9	**Establish ADS-B Separation Standards**								
9.1.1	Radar augmentation with ADS-B to support mixed equipage in terminal airspace	ORV>AK	2000	9					
9.2.1	Radar augmentation with ADS-B to support mixed equipage in en route airspace	ORV<AK	2000	9					

Define & Develop stage includes tasks in Appendix A: 1 (Operational Concept), 3 (Maturity of Concepts & Technology, 4 (Operational Procedures), 5 (Human Factors Issues), 6 (End-to-End Performance and Technical Requirements, 7 (Interoperability Requirements, and 9 (Avionics and Ground Systems)

Evaluation stage includes tasks 2 (Benefits and Constraints), 8 (Operational Safety Assessment), and 10 (Operational Test and Evaluation)

Implementation stage includes tasks 11 (Equipment Certification), 12 (Operational Approval), and 13 (Implementation Transition)

Figure 10. Safe Flight 21 Target Schedule

Target Schedule for SafeFlight 21 Applications

Define & Develop | Evaluate | Implement

#	Name (with development phase if needed)	Location	OpEval Year	Importance low 0 - 10 high
1	**Weather and Other Information to the Cockpit**			
1.1.1	wx alerts)	AK	2000	9
1.1.2	products)	AK	2001	9
2	**Cost Effective CFIT Avoidance**			
2.1	Low cost terrain situational awareness	AK	2000	10
2.2	Increased access to terrain-constrained low altitude airspace	AK	2001	9
3	**Improved Terminal Operations in Low Visibility**			
3.1.1	Enhanced visual approaches (existing procedures using ADS-B only)	ORV	1999	9
3.1.2	Enhanced visual approaches (new procedures, ADS-B only)	ORV	2000	9
3.1.3	Enhanced visual approaches (new procedures, ADS-B and TIS-B)	ORV	2000	6
3.2.1	Approach spacing (visual approaches)	ORV	2000	9
3.2.2	Approach spacing (instrument approaches)	ORV	2001	9
3.4	Departure spacing/clearance (VMC in radar)	ORV	2000	
4	**Enhanced See and Avoid**			
4.1.1	Enhanced visual acquisition see-and-avoid (using ADS-B only)	ORV>AK	1999	7 / 9
4.1.2	Enhanced visual acquisition see-and-avoid (using ADS-B and TIS-B)	ORV<AK	2001	6 / 9
4.2.1	Conflict detection	ORV>AK	2000	10 / 8
4.2.2	Conflict resolution	ORV	2002	10
5	**Enhanced En Route Air-to-Air Operations**			
5.2.1	Pilot situational awareness beyond visual range	AK	2000	9
6	**Improved Surface Surveillance and Navigation for the Pilot**			
6.1.1	Runway and final approach occupancy awareness (ADS-B only)	ORV>AK	2000	8
6.1.2	Runway and final approach occupancy awareness (ADS-B and TIS-B)	ORV	2001	6
6.2	Airport surface situational awareness	ORV>AK	2001	8
7	**Enhanced Surface Surveillance for the Controller**			
7.1	Enhance existing surface surveillance with ADS-B	ORV	2000	8
7.2	Surveillance coverage at airports without existing surface surveillance	ORV	2001	8
8	**ADS-B Surveillance in Non-Radar Airspace**			
8.1	Center situational awareness with ADS-B	AK	2000	9
8.2	Radar-like services with ADS-B	AK	2000	9
8.3	Tower situational awareness beyond visual range	AK	2000	8
9	**Establish ADS-B Separation Standards**			
9.1.1	Radar augmentation with ADS-B to support mixed equipage in terminal airspace	ORV>AK	2000	9
9.2.1	Radar augmentation with ADS-B to support mixed equipage in en route airspace	ORV<AK	2000	9

Timeline columns: 1999 | 2000 | 2001 | 2002 | Beyond

Slip in schedule

Define & Develop stage includes tasks in Appendix A: 1 (Operational Concept), 3 (Maturity of Concepts & Technology, 4 (Operational Procedures), 5 (Human Factors Issues), 6 (End-to-End Performance and Technical Requirements, 7 (Interoperability Requirements, and 9 (Avionics and Ground Systems)

Evaluation stage includes tasks 2 (Benefits and Constraints), 8 (Operational Safety Assessment), and 10 (Operational Test and Evaluation)

Implementation stage includes tasks 11 (Equipment Certification), 12 (Operational Approval), and 13 (Implementation Transition)

Figure 11. Safe Flight 21 Adjusted Target Schedule

Section 1

Introduction

Safe Flight 21 is a cooperative government/industry effort to develop enhanced capabilities for Free flight based on evolving Communications, Navigation and Surveillance (CNS) technologies. Safe Flight 21 will demonstrate the in-cockpit display of traffic, weather and terrain information for pilots and will provide improved information for controllers. The new technologies on which this program is based include the Global Positioning System (GPS), Automated Dependent Surveillance – Broadcast (ADS-B), Flight Information Services (FIS), Traffic Information Service – Broadcast (TIS-B), and their integration with enhanced pilot and controller information displays. Safe Flight 21 will evaluate the safety, service and procedure improvements these technologies make possible.

1.1 Purpose

The purpose of this Master Plan is to present a Safe Flight 21 plan for incrementally specifying, developing and evaluating the operational enhancements called for in the RTCA Joint Government/Industry Roadmap[1]. This plan states the objectives of the Safe Flight 21 Program and the approach the FAA and industry will take to work on these operational enhancements.

As used in this document, *Safe Flight 21 Operational Enhancements* refers to the CNS-based capabilities that have been selected by the Free Flight Select Committee. The FAA is executing the *Safe Flight 21 Program* that supports the development of these selected operational enhancements. Major efforts by industry will also be expended in support of developing the *Safe Flight 21 Operational Enhancements.* The FAA and industry roles in Safe Flight 21 are complementary. Planning for the FAA's Safe Flight 21 Program requires a perspective that spans all organizations involved in Safe Flight 21 and their respective roles. This plan adopts this broader perspective. Within this context, activities by the FAA are noted and presented in greater detail.

This Master Plan provides a consistent picture of the Safe Flight 21 Program. It is a living document that supports the evolutionary process described in Section 2. As progress is made and knowledge about the systems is gained, the Master Plan will be updated to reflect the current state of the program. The Master Plan will trace the connections between high-level objectives and critical low-level details that must be addressed in technical activities.

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1 RTCA Select Committee, Joint Government/Industry Roadmap for Free Flight Operational Enhancements, August, 1998.

Synopses of these connections will enable informed prioritization of Safe Flight 21 actions based on realistic, technically valid expectations.

1.2 Background

This section describes the Safe Flight 21 program context and illustrates issues that have shaped the objectives and approach of the program.

1.2.1 CNS/ATM Evolution in the NAS, Task Force 3

In 1995 the FAA Administrator asked RTCA to develop an aviation community consensus regarding free flight implementation. The primary guiding principle for Task Force 3, the task force established to respond to the Administrator's request, was that the transition to mature free flight will be benefits-driven and time-phased. The mature free flight is a vision that will change over time and the community could not afford to wait for long-term development initiatives to produce the benefits. The most far-reaching recommendation out of this task force was for the establishment of a government/industry Free Flight Steering Committee. Out of that committee has come a process to establish implementation strategies and milestones, to review progress and to identify new free flight opportunities.

1.2.2 Flight 2000

Flight 2000 was an aggressive initiative to deploy and evaluate selected planned air traffic management systems for the year 2005 NAS. The objectives of the Flight 2000 program were to demonstrate safety and efficiency benefits of new technology and improved procedures, to evaluate communication, navigation, and surveillance (CNS) transition issues, to streamline avionics development, certification, and installation, and otherwise reduce the risks for accelerated NAS modernization. These integrated demonstrations and validation activities would have begun in September 2000. This initiative was too encompassing, too expensive and lacked stakeholder buy-in.

1.2.3 Capstone

Within the Alaskan Region, Flight 2000 served as the "capstone" for many additional initiatives, providing a common umbrella for planning, coordination, focus, and direction with regard to expansion of current infrastructure and development of the future NAS. A few additional "technology-driven" initiatives were recommended in a 1995 NTSB Alaska Safety Study[2]. The Alaskan Region's "Capstone Program" is an accelerated effort to improve aviation safety and efficiency through installation of government-furnished Global

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[2] *Aviation Safety in Alaska*, NTSB Report SS-95-03, November 28, 1995.

Positioning System (GPS)-based avionics and data link communications suites in most commercial aircraft serving the Yukon-Kuskokwim delta area.

Alaska has approximately 10% of the nation's air carriers or commercial operators. Historically, this 10% generates approximately 35% of the nation's air carrier / commercial operator accidents. During the three year period from 1994 to 1996, there were 112 accidents involving Alaska's air carrier /commercial operator's - a recent study of those accidents indicated that 38% might have been avoided by availability of information in the cockpit of the type provided by modern equipment (position relative to terrain and traffic, and "real time" weather information). The Capstone Initiative will attempt to validate these safety projections. The Bethel and Y-K delta area is the Capstone test bed; it is served by approximately 25 percent of the commercial aircraft in Alaska and it has a proportionate number of Alaskan accidents.

1.2.4 CAA ADS-B Program

In 1996 the CAA began a program to develop an Enhanced Collision Avoidance System (ECAS) based on the Automatic Dependent Surveillance – Broadcast (ADS-B) technology in an effort to achieve an improved separation tool. The CAA ADS-B Program consists of three phases:

- Phase I is intended to achieve fleetwide installation of an ADS-B based Cockpit Display of Traffic Information (CDTI) system for use as a pilot aid to visual acquisition of other traffic for see and avoid. The objectives of the Phase I OpEval are three-fold: (1) to demonstrate ADS-B technology, (2) to evaluate specific air-air and air-ground applications, and (3) to develop a wide support base for the advancement of ADS-B implementation.
- Phase II is intended as a software upgrade to the Phase I system to provide conflict detection functionality.
- Phase III is intended as a software upgrade to the Phase II system to provide resolution advisories, resulting in full conflict detection and resolution (CD&R) functionality.

1.2.5 NAS Modernization Task Force

In November, 1997, the FAA Administrator appointed a Task Force to identify and address the needs of the aviation community for National Airspace System (NAS) modernization and the barriers to moving forward with such a modernization activity. One of the recommendations that came out of that task force was a need to refocus the CNS programs based on the observation that the CNS modernization goals were at risk. The CNS programs should take on a more risk reduction focus. One of the significant elements of risk was the level of interaction with the industry that must produce, install and use the new CNS

capabilities. To minimize this risk, it was recommended that the RTCA provide the forum for identifying the high level requirements and coordinating the industry/FAA efforts. The RTCA is, in fact, providing this forum through the Safe Flight 21 steering group structure described in Section 2.5.

1.2.6 Joint Roadmap

One of the first RTCA activities to reduce the risk to the CNS programs was to identify the Flight 2000 Subgroup of the Free Flight Select Committee, to work with representatives of the FAA Flight 2000 program to develop the *Roadmap for Free Flight Operational Enhancements*.[3] This document defines nine CNS-based operational enhancements at a high level, (see Table 1-1) identifies types of potential benefits, gives examples of risks and issues to be resolved, and specifies the emphasis and locations where these enhancements will be evaluated. The *Roadmap* represents a common vision of 9 high priority enhancements that includes government, industry and user perspectives. The *Roadmap* also proposed a new collaborative way of doing business to enhance the NAS that is intended to gain and maintain buy-in and political support for FAA action on these 9 enhancements

Industry and user buy-in is critical for avionics-based NAS enhancements. The need for buy-in is compounded for enabling systems (such as ADS-B) whose performance and benefits are heavily dependent on breadth of equipage. The *Roadmap* begins to identify the risks of capabilities that require a considerable percentage of equipage before benefits accrue and the difficulty of justifying equipment purchases before if there is a significant delay before benefits materialize. This is a "chicken and egg" problem that must be addressed. The *Roadmap* also identifies additional benefits and synergies that are expected if multiple capabilities are implemented together.

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3 RTCA Select Committee, Joint Government/Industry Roadmap for Free Flight Operational Enhancements, August, 1998.

Table 1-1. Operational Enhancements[4]

	Operational Enhancement	Ohio Valley	Alaska
1	Weather and Other Information to the Cockpit		✓
2	Cost Effective CFIT Avoidance		✓
3	Improved Terminal Operations in Low Visibility	✓	
4	Enhanced See and Avoid	✓	✓
5	Enhanced En Route Air-to-Air Operations	✓	✓
6	Improved Surface *Surveillance* & Navigation for the Pilot	✓	✓
7	Enhanced Surface Surveillance for the Controller	✓	✓
8	ADS-B Surveillance in Non-Radar Airspace		✓
9	ADS-B *Surveillance in Radar Airspace*		✓

1.2.7 Safe Flight 21

The FAA has responded to the recommendation in the *Roadmap* by establishing the Safe Flight 21 program in AND-500 as an umbrella to include activities that work toward the operational evaluation of the enhancements identified in the *Roadmap*. Numerous initiatives were underway at the time including helicopter navigation and surveillance in the Gulf of Mexico, ATIDS at DFW, helicopter tracking in Hawaii, NASA in Minneapolis, CPDLC, Capstone in Alaska and the CAA activities in the Ohio Valley. RTCA analyzed the needs for the Safe Flight 21 work and chose Capstone and the CAA activities to focus on. Both of these activities are now part of the Safe Flight 21 program as shown in Figure 1-1.

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4 The wording in italics has been modified from the enhancement titles of the original roadmap document to make them more consistent with the descriptions of the enhancements in that document. The shaded boxes under Ohio Valley and Alaska indicate where evaluation at these locations differs between the *Roadmap* (checks) and the current plans for Safe Flight 21.

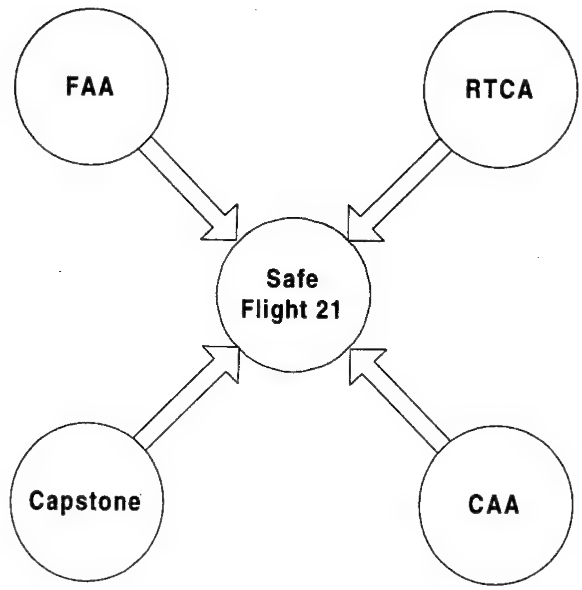

Figure 1-1. Contributors to the Safe Flight 21 Program

Safe Flight 21 is a new approach to risk mitigation and NAS modernization that combines resources of both industry and the FAA to improve safety, capacity, efficiency, utility and reduce costs.

The *Roadmap* indicated that in the interest of containing the scope of the program these two locations (the Ohio Valley and Alaska) should be the focus of the Safe Flight 21 efforts. Based on the aircraft populations and the airspace issues in each of these locations, the nine operational enhancements will be evaluated in the locations listed in Table 1-1.

The Safe Flight 21 Steering Group, a group under the purview of the RTCA Free Flight Select Committee (see Section 2.5), interprets the scope within these enhancements that should be addressed by Safe Flight 21 by focusing on a set of specific applications. It will be these applications that will be evaluated by the Safe Flight 21 program. The applications that will be evaluated under each of the enhancements is discussed in Section 3.

1.3 Organization of this Master Plan

This document represents the current knowledge and planning horizon of the Safe Flight 21 program. The description of the program, its stakeholders, and how the information flows and decisions are made is found in Section 2. Section 3 maps the operational enhancements to the applications that will be evaluated, including some applications considered "in-scope" but beyond the time and resources of the program. Section 4 captures the Safe Flight 21 multiyear plan by including a description of the planning process and the high level program

schedule. Section 5 provides additional insight into the manner in which the program will address safety, risk, human factors and benefits.

1.4 Relationship to Other Documents

This Master Plan has its genesis in the Joint Government/Industry Roadmap for Free Flight Operational Enhancements[5] (August 1998) which, in turn, was based on the Free Flight Final Report of Task Force 3[6]. The *Roadmap* document identified the need for evaluation of nine operational enhancements for which there was a consensus among the aviation community along with locations for the evaluations and an approximate timetable.

Specific ADS-B applications in this Master Plan were selected by the Safe Flight 21 Steering Group, drawing in part from the ADS-B MASPS and from the Draft RTCA SC-186 ConOps, the Joint ConOps and the Air Traffic 2005 ConOps. More specific operational concepts for Flight Information Systems (FIS) are expected to draw on RTCA SC 169 WG-3 (now SC-195). The information gained from the Safe Flight 21 Operational Evaluations will be fed back into the concept of operations and the system architecture.

The information flow in Safe Flight 21 and the relationship of the various documents are explained in more detail in Section 2.6.

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5 RTCA Select Committee, *Joint Government/Industry Roadmap for Free Flight Operational Enhancements*, August, 1998.

6 RTCA Task Force 3, *Final Report of RTCA Task Force 3 Free Flight Implementation*, October 1995.

Section 2

Safe Flight 21 Program

2.1 Safe Flight 21 Objectives

The primary objective of the Safe Flight 21 program is to enable and expedite decisions by stakeholders on implementing nine operational enhancements:

1. Weather and Other Information to the Cockpit
2. Cost Effective CFIT Avoidance
3. Improved Terminal Operations in Low Visibility
4. Enhanced See and Avoid
5. Enhanced En Route Air-to-Air Operations
6. Improved Surface Surveillance and Navigation for the Pilot
7. Enhanced Surface Surveillance for the Controller
8. ADS-B Surveillance in Non-Radar Airspace
9. Establish ADS-B Separation Standards

Government and industry will jointly demonstrate and evaluate these enhancements in a real-world operational environment. In doing these demonstrations and evaluations, the enhancements will be refined and stress tested. Prior to committing the FAA and the users to a full scale implementation of these enhancements, there needs to be a consensus among the stakeholders (including the FAA) of the feasibility and business case for the enhancements.

Another objective of the Safe Flight 21 program is to reduce the risk of implementing the operational enhancements listed above. Certification and obtaining operational approval from the FAA represent significant risks to achieving these enhancements. Thus, the program will have an objective to develop innovative processes to expedite the certification and operational approval of these enhancements when they are shown to be feasible and useful to the stakeholders.

2.2 Safe Flight 21 Scope

A first step toward developing and evaluating these nine high-level enhancements is to clarify the specifics of what they include and develop top-level details of the operations involved and the systems required. The Safe Flight 21 Steering Group has taken this step and defined the scope of Safe Flight21 in terms of specific applications (within the enhancements) that will be developed and evaluated. The applications within each enhancement are discussed in Section 3.

2.3 Safe Flight 21 Constraints

There are a number of general constraints that the Safe Flight 21 program is cognizant of and has taken into consideration. First, stakeholder "buy-in" must be maintained. The FAA is not free to develop independent plans for this program without industry consensus. In fact, the FAA will not work on any of these enhancements unless there is a segment of the industry interested in working with the FAA on developing, demonstrating or evaluating the enhancement. Second, tangible progress on the enhancements must be demonstrated early. The enhancements that have been requested through the RTCA process affect the "bottom line" or the access to the National Airspace System (NAS) for many of the stakeholders. Delays in achieving these enhancements will adversely affect those stakeholders. As a corollary to the second constraint, these enhancements, because they require development, are best demonstrated and evaluated incrementally. This will reduce the risk of failure of achieving these enhancements.

As with all FAA programs there are fixed funding limits set by the FY00 budget. This also includes limits on the contract support that the Safe Flight 21 program office can receive.

2.4 Safe Flight 21 Stakeholders

The success of the Safe Flight 21 program depends on establishing a "win-win" situation for all stakeholders whose support is required to meet the program's objectives. The program stakeholders from the perspective of the Safe Flight 21 program office are both internal and external to the FAA. The external stakeholders interface with the Safe Flight 21 program through the Safe Flight 21 Steering Group whose members have been selected in coordination with the RTCA Free Flight Steering Committee by drawing on membership of the Free Flight Select Committee.

The stakeholders that have participated in the Safe Flight 21 program to date include those who have worked towards operational evaluations in the Ohio Valley, on Capstone and for coordination of the Safe Flight 21 Program overall. Many of these organizations are listed in Tables 2-2 through 2-4.

Table 2-2. Participation in Ohio Valley

Participant	Role
CAA	Project Leadership/Coordination
FedEx	Test Operations
UPS	Test Operations, Public Relations
Airborne Express	Facilities, Radios, Maintenance, Fuel, Public Relations, Computers, Flight Safety, Flight Control, Ground Safety, Ramp, Test Operations
Ohio University	Test Operations
Culmulus Consulting	Test Operations
MIT LL	Test Operations
U.S. Navy	Test Operations
AND	Safe Flight 21 Program Management, Public Relations, Planning
ATO	Air Traffic Control, Test Operations
ACT	Test Operations, Ground Station, Safety
AFS	Test Operations
ARW	Air Traffic Control
MITRE/CAASD	Test Operations, Ground Station, Human Factors, Technical/Certification, Planning
Lockheed Martin	Test Operations, Ground Station, Public Relations
NASA	Test Operations, Human Factors
Dayton TRACON	Air Traffic Control
Airborne Pilot Union	Test Operations, Facilities
FedEx Pilot Union	Test Operations
ILN Controllers	Facilities, Air Traffic Control
ZID Controllers	Air Traffic Control
NATCA	Air Traffic Control, Test Operations
Harris	Ground Station
Sensis	Ground Station
Trios	Ground Station, Planning
UPS AT	Cockpit Avionics

Table 2-3. Participation in Alaska

Participant	Role
AAL-1S	Capstone Program Office
AAL-7	Assistant Chief Counsel
AAL-40	Resource Management
AAL-200	Flight Standards
AAL-400	Airway Facilities
AAL-500	Air Traffic
AAL-600	Airports
ANI	NAS Implementation Center
ACE	Aircraft Certification
AUA	MicroEARTS modifications
AFS	Test Operations
UPS AT	Cockpit Avionics/Ground Stations
ARNAV	FIS data
DoD	SUA coordination
Alaska DOT	Alaskan Department of Transportation
Alaskan Air Carrier Association	Commercial Users
Alaskan Airmen's Association	Pilots
Alaskan Air Safety Foundation	Safety
AOPA	General Aviation Users
ALPA	Pilots
University of Alaska	Training and Safety Study
MITRE/CAASD	Ground Broadcast Server, Coordination

Table 2-4. Participation in Safe Flight 21 Overall Coordination

Participant	Role
AND	Program Management, Safe Flight 21 Steering Group, Ops/Proc, Cost/Benefit
AOPA	Safe Flight 21 Steering Group
ALPA	Safe Flight 21 Steering Group, Ops/Proc
AFS	Safe Flight 21 Steering Group, Cost/Benefit
AIR	Safe Flight 21 Steering Group
ATO	Safe Flight 21 Steering Group,

	Cost/Benefit, Ops/Proc
AAL	Safe Flight 21 Steering Group
CAA	Safe Flight 21 Steering Group Ops/Proc, Cost/Benefit
NATCA	Safe Flight 21 Steering Group, Ops/Proc
ASD	Safe Flight 21 Steering Group, Cost/Benefit, Tech/Cert
MITRE/CAASD	Safe Flight 21 Steering Group, Cost/Benefit, Ops/Proc, Tech/Cert, Planning
SETA	Cost/Benefit
Marconi	Program Office, Cost/Benefit
NASA	Cost/Benefit
VOLPE	Risk Management, Cost/Benefit, Tech/Cert
AOPA	Cost/Benefit
UPS	Cost/Benefit, Ops/Proc, Tech/Cert
MCR	Cost/Benefit
ARR	Cost/Benefit, Ops/Proc
RTI	Cost/Benefit
JHU/APL	Ops/Proc, Tech/Cert
SAAB Dynamics AB	Tech/Cert
PMEI	Tech/Cert
EUROCAE	Tech/Cert
MIT/LL	Tech/Cert
Swedavia	Tech/Cert
AIR	Tech/Cert
ASR	Tech/Cert
ACT	Tech/Cert
Eurocontrol	Tech/Cert
Swedish CAA	Tech/Cert

2.5 Safe Flight 21 Structures, Roles and Responsibilities

The structure for coordinating Safe Flight 21 as a whole is generalized from that used by the FAA, RTCA and the CAA to develop the initial set of Enhanced Visual Acquisition ADS-B applications which were operationally evaluated in 1999 (see Figure 2-1). The RTCA's Free Flight Steering Committee is the focus of industry consensus on the new CNS capabilities. Through the Free Flight Select Committee the enhancements for Safe Flight 21 were defined and their development and evaluation will be monitored. The Safe Flight 21 Steering Group is the focus of ongoing coordination between stakeholders and the Safe Flight 21 program.

To move forward toward implementation, the evaluations must show that the enhancements are feasible, useful and cost beneficial. There are three subgroups under the Safe Flight 21 Steering Group that address these issues: the Operations/Procedures subgroup, the Cost/Benefit subgroup, and the Technical/Certification subgroup. The roles for the steering committee and these subgroups have been defined in the Safe Flight 21 Steering Group Terms of Reference.

Safe Flight 21 Steering Group

- Provides on-going guidance on the scope, priority, and schedule of evaluation activities for the nine operational enhancements.
- Oversees the objective assessment of candidate ADS-B technologies. The assessment will identify the capability, cost and ability of each technology to satisfy the requirements of the operational capabilities identified in the Safe Flight 21 Roadmap.
- Establishes metrics to be used in the evaluation of operational benefits and the assessment of costs.
- Analyzes the cost and benefit of the nine operational enhancements and makes recommendations to the Free Flight Select Committee on which enhancements or combination of enhancements yield the greatest return on investment in terms of safety, efficiency, capacity and human productivity.
- Should changes in the roadmap become necessary, the Safe Flight 21 Steering Group will present specific recommendations and rationale to the Free Flight Select Committee for action.

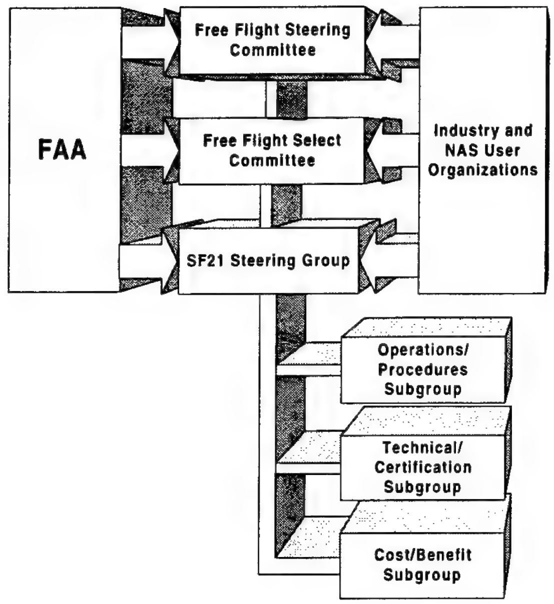


Figure 2-1. Safe Flight 21 Steering Group Organization

Operations and Procedures Subgroup

The operations and procedures subgroup is responsible for leading and coordinating the Safe Flight 21 detailed application description development for each of the Safe Flight 21 applications and will also provide guidance and oversight of procedures development for each of the Safe Flight 21 evaluations in the Ohio Valley with the Cargo Airline Association (CAA) and in Alaska with the Capstone initiatives. The subgroup will ensure that pilot, controller, operator, FAA air traffic management and flight standards issues are addressed. The group will also coordinate with RTCA SC-186, 193 and 195 and the FAA Integrated Requirements Team as appropriate. The group will work with the Technical/Certification subgroup to define how each of the technologies is used to gain a beneficial capability. Those definitions will be used as the basis for certification criteria.

Technology and Certification Subgroup

The Technology and Certification subgroup will oversee the ADS-B system link alternatives evaluation, define high-level system requirements (ground

station/avionics), and coordinate requirements for equipment certification and operational approvals necessary for operational evaluations and ultimately NAS-wide implementation. The subgroup will assist the Cost/Benefit subgroup with defining avionics and group system costs, and will work with the Operations/Procedures subgroup to define the intended function of each technology as a basis for certification.

Cost/Benefit Subgroup

The Cost/Benefit subgroup will collaborate with the other Safe Flight 21 subgroups, FAA System Engineering, manufacturers and the operators to obtain cost and benefit data and work with the FAA on a cost/benefit analysis. The analysis will provide information on the trade-off between the differing levels of capability and different architecture and technology options that are explored within Safe Flight 21. This analysis will serve as a basis for recommendations and guidance by the Safe Flight 21 Steering Group. Initial focus will be placed on assessing the cost and benefits of the three candidate ADS-B/FIS links as they pertain to the nine operational enhancements. The Cost/Benefit subgroup will collaborate with the Technical/Certification subgroup and manufacturers to define the costs of link alternatives and with the Operations/Procedures subgroup to quantify and qualify economic and safety benefits derived from each capability and their integration.

The Safe Flight 21 evaluations are being conducted in the Ohio Valley and in Alaska. The Ohio Valley evaluation is built on stakeholder participation in the planning and conduct of the evaluations. The organizational structure of the Ohio Valley effort is shown in Figure 2-2. In this structure the stakeholders form a steering committee to ensure that their interests in the evaluation are addressed. The day-to-day activities of the planning and execution of the evaluation are managed by the Operational Evaluation Coordination Group (OCG). Beneath the OCG are subgroups that plan the various aspects of the evaluation.

In Alaska the FAA-managed Capstone Program is the focal point for planning and conducting the evaluations. The organizational structure of this effort is shown in Figure 2-3. The Capstone Program Office is staffed and supported through temporary assignments by the Alaskan Region line organizations and the Regional Administrator's staff. Each line organizational representative is responsible to develop individual detailed work plans for each aspect of the program to which they are the lead. Staffing includes program support personnel, headquarters liaisons, and representatives from regional Flight Standards, Air Traffic, Airway Facilities, NAS Implementation, Aircraft Certification, logistics and Aviation System Standards organizations. The Capstone VFR-to-IFR Test and Evaluation Master Plan (TEMP) is produced by the Capstone Operations Group (COG), formed by the Capstone Program Office. It presents program background, system descriptions, required resources and test management, organization, and planning activities that will be active in evaluating the use of ADS-B to provice radar-like service in Bethel,

AK. The membership of the COG will also be in place to evaluate other applications as desired.

The communication between the RTCA, FAA and the stakeholder groups is facilitated by the fact that the membership of the subgroups of the Safe Flight 21 Steering Group Organization and the coordination groups in the Ohio Valley and Alaska have a high degree of overlap. FAA provides leadership, coordination and support to this process. The FAA assumes the co-chair role on the Safe Flight 21 Steering Group and also on the coordination groups. Safe Flight 21 Program Office staff and representatives of stakeholder organizations within the FAA are members of the various subgroups.

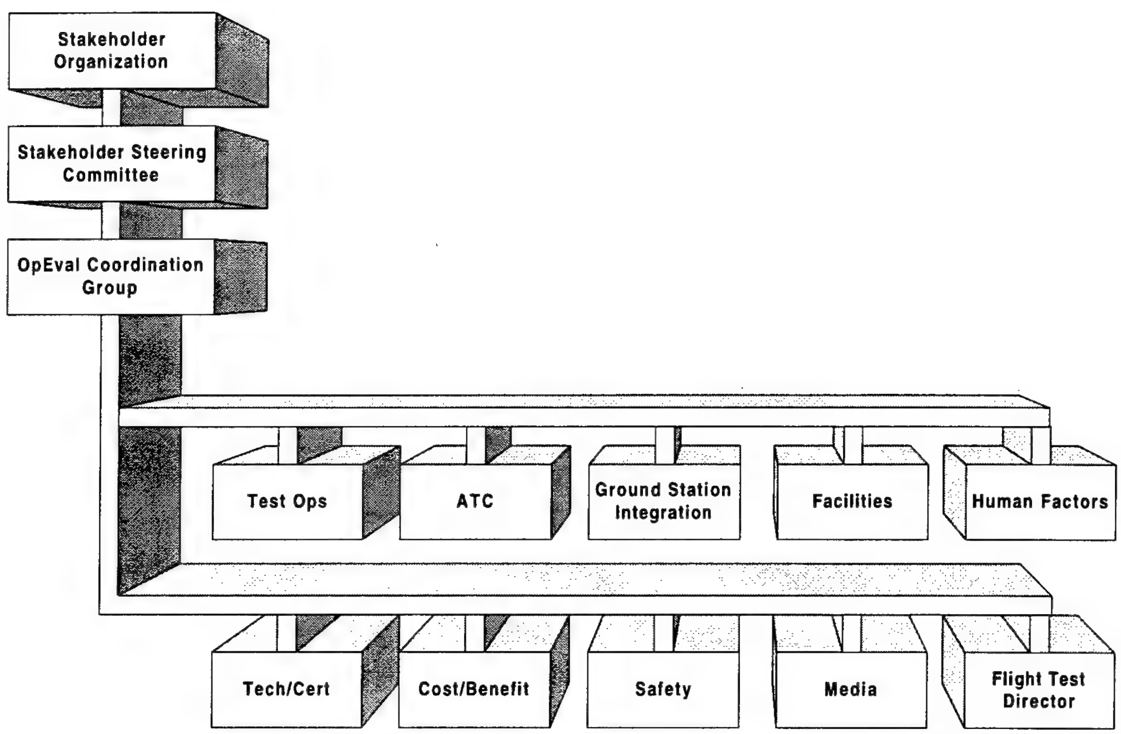


Figure 2-2. Ohio Valley Operational Evaluation Organization

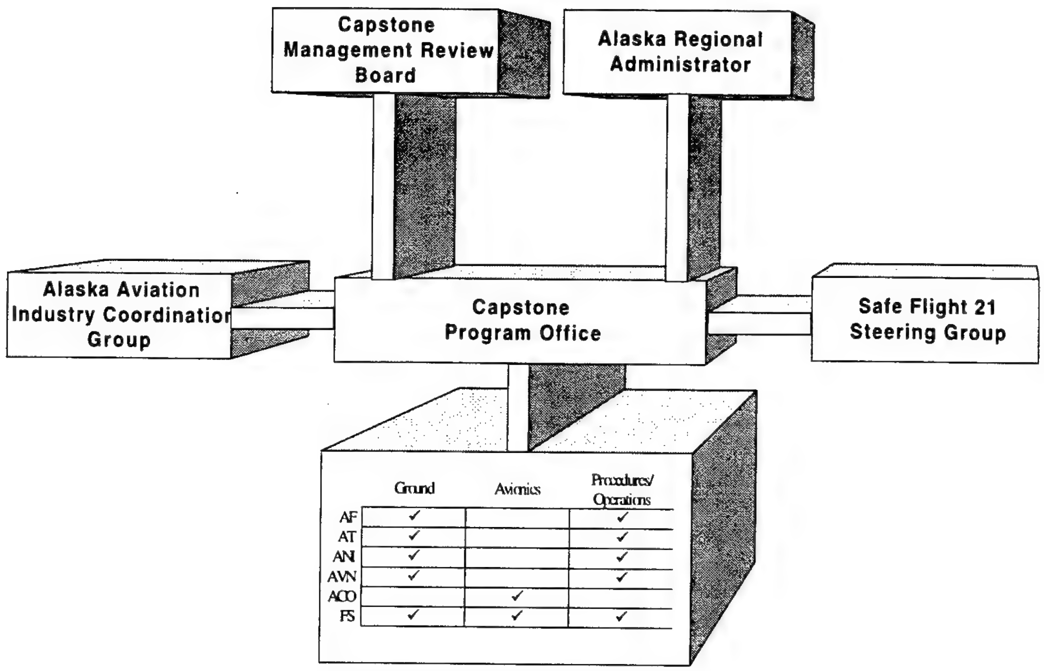


Figure 2-3. Capstone Operational Evaluation Organization

2.6 Safe Flight 21 Information Flows and Decision Making

The activities and progress of Safe Flight 21 is based on stakeholder consensus. Therefore, the informational flow and decision making of this program is designed to involve the stakeholders. As depicted in Figure 2-4, the RTCA *Roadmap*, other RTCA documents and the NAS Architecture are the main drivers of Safe Flight 21 activities. This document (the Safe Flight 21 Master Plan) uses the material in the *Roadmap*, the MASPS and the architecture to define the sequence of applications to be investigated. The control of this document is shared between the FAA and the RTCA Safe Flight 21 Steering Group.

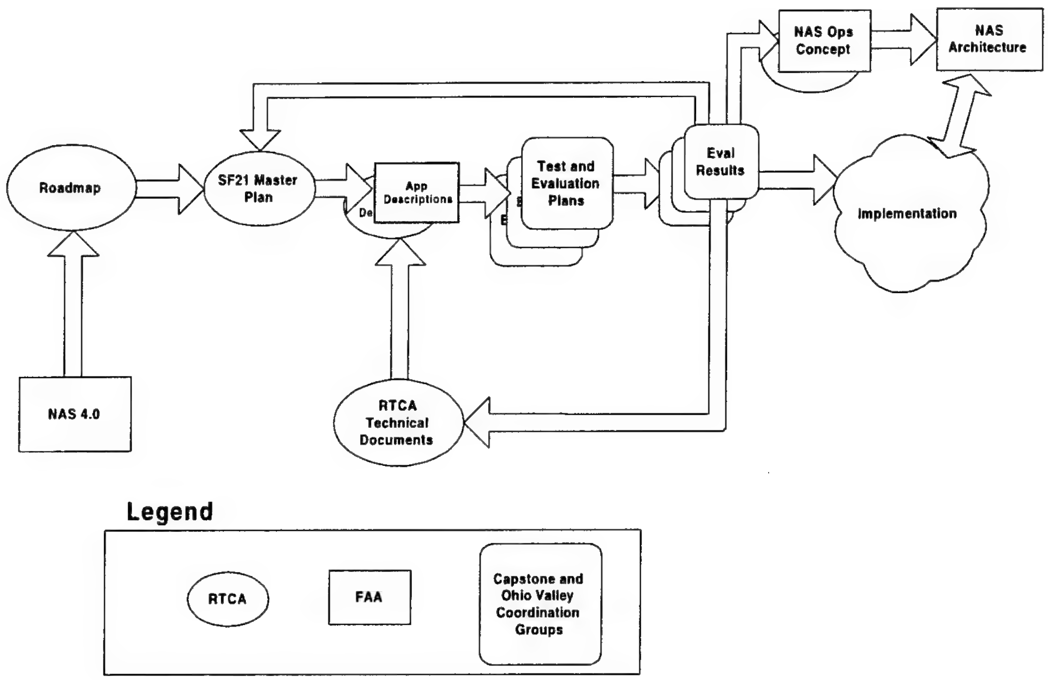


Figure 2-4. Safe Flight 21 On-Going Information Flows

For each Operational Evaluation there will be a Test and Evaluation Master Plan. The control of this document will be shared between the Safe Flight 21 program office and the OpEval Coordination Group for the particular OpEval.

Out of each Operational Evaluation will come a set of results. These results include data, analyses of that data, and any consensus on what the operational capabilities should be and their benefits. This information is then fed back into the Master Plan and fed forward into the system Operational Concept. These validated, stakeholder embraced operational concepts will confirm (or identify corrections to) planned FAA and stakeholder architectures.

2.7 Transition to Implementation

Safe Flight 21 will help provide knowledge, experience and confidence that are needed for the FAA and the aviation community to make decisions on ADS-B/CDTI and capabilities that are based-on or synergistic with it. Fundamental to the Safe Flight 21 strategy and to the FAA's plans for ADS-B is that avionics equipage should be voluntary and that decision-making and implementation should be incremental.

Throughout the National Airspace System airspace users differ in their operations and equipment. Regionally and locally the NAS differs in traffic levels and mixtures, in infrastructure capabilities, and in weather and terrain. As a natural result of these differences the relative attractiveness of new avionics-based capabilities will be highest in certain niches or pockets, and lower elsewhere. With time and experience and continued incremental improvement, the business-case for these capabilities may someday be broadly compelling. But initial equipage that can provide this experience, confidence, and opportunity for continued improvement must begin in these niches and build. (And, as expressed by the Technology Adoption Model in Appendix B, the initial foothold is only the first step in this incremental process.)

The Safe Flight 21 operational evaluations are taking place in two locations that promise large early benefits from equipage. In the Alaska Yukon-Kuskokwim delta the safety benefits to air-taxi operators (generally flying GA-type aircraft) are expected to be strongly demonstrated by equipping aircraft in a location that is relatively isolated. In the Ohio Valley, CAA hub operations at night offer efficiency improvements from near 100% equipage based on decisions made by individual carriers.

In coordination with the aviation community, the FAA is defining a strategy for extending the evaluations of Safe Flight 21 into additional and permanent pockets of capability and ground infrastructure. This is summarized in Figure 2-5 which illustrates three levels within this continuum with examples of possible capabilities at each level.

FAA strategy in this regard is to encourage voluntary avionics equipage by supporting early highly-beneficial capabilities. One aspect of this is early selection of a long-term link decision for ADS-B which is a prerequisite for implementation beyond Safe Flight 21. Another aspect is deployment of supporting infrastructure where it is sufficiently cost-beneficial to do so. (See Figure 2-6)

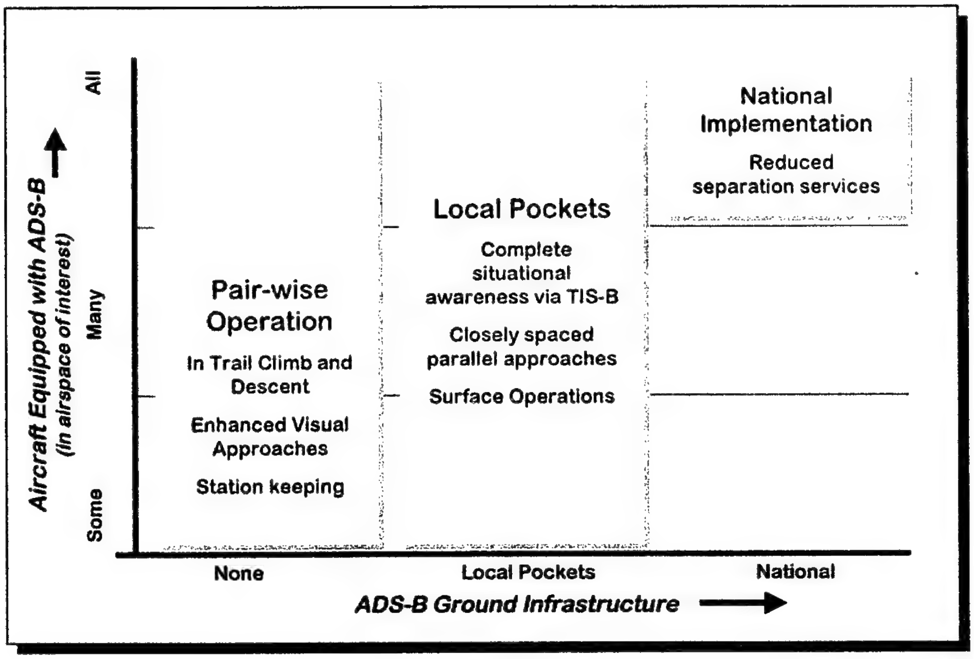


Figure 2-5. ADS-B Equipage and Transition Profile

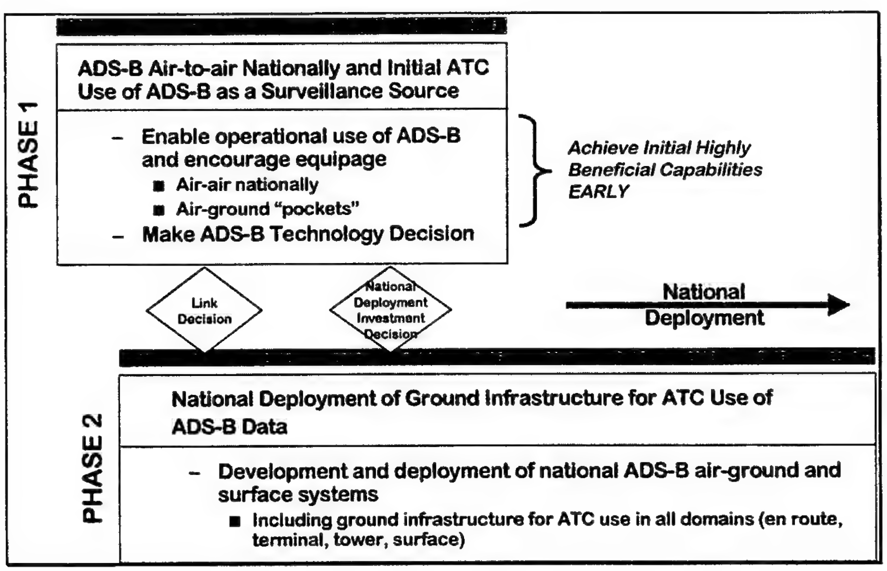


Figure 2-6. ADS-B Implementation Phases

The FAA realized that many new technology research and implementation efforts do not fit the normal acquisition program mold and developed a process that would allow for tailoring the AMS on a case-by-case basis. Figure 2-7 summarizes the flow of a research effort from establishing a need through acquisition and implementation. There are three logical decision points in this process where the FAA will review the data generated by the evaluation and cost benefit analysis for a given research effort and determine the next steps to be taken to move the technology towards implementation.

The process for decision-making and implementation has been embraced by the Safe Flight 21 program and it is expected that the decision and review process will be different for different applications. A primary determinant will be the nature and level of ground infrastructure required. The FAA has defined three paths toward implementation for applications and locations that differ in this way. These paths are shown in Figure 2-8 which builds off of the generic research effort flow chart shown in Figure 2-7. The upper path corresponds to applications based primarily on avionics used aircraft-to-aircraft without significant ground infrastructure. The lower path corresponds to limited implementations of infrastructure in geographic pockets where user equipage and benefits justify early usage. The central path corresponds to the standard FAA Acquisition Management System (AMS) for large-scale acquisitions and modernization.

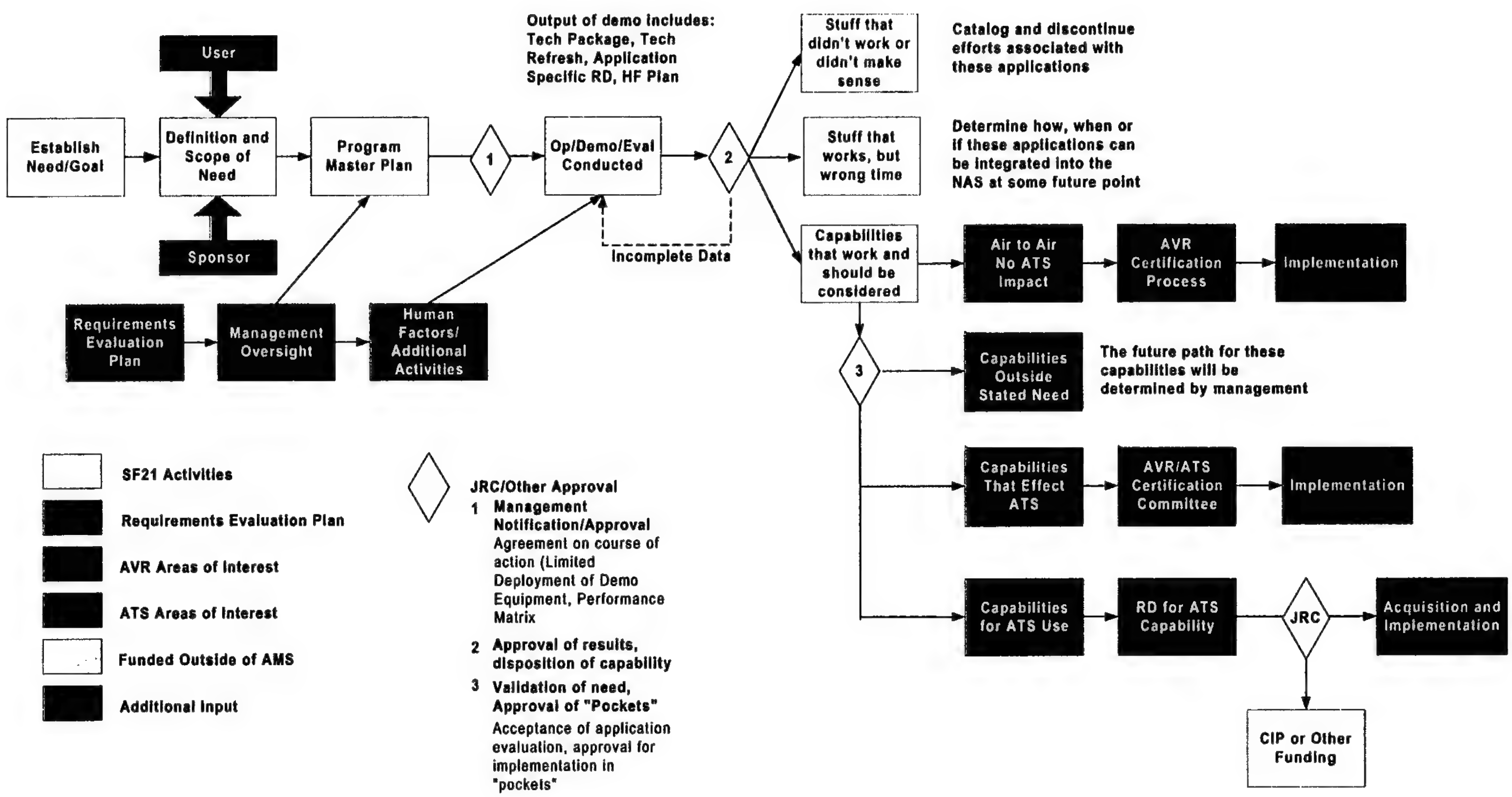


Figure 2-7. Research Efforts and the AMS Process

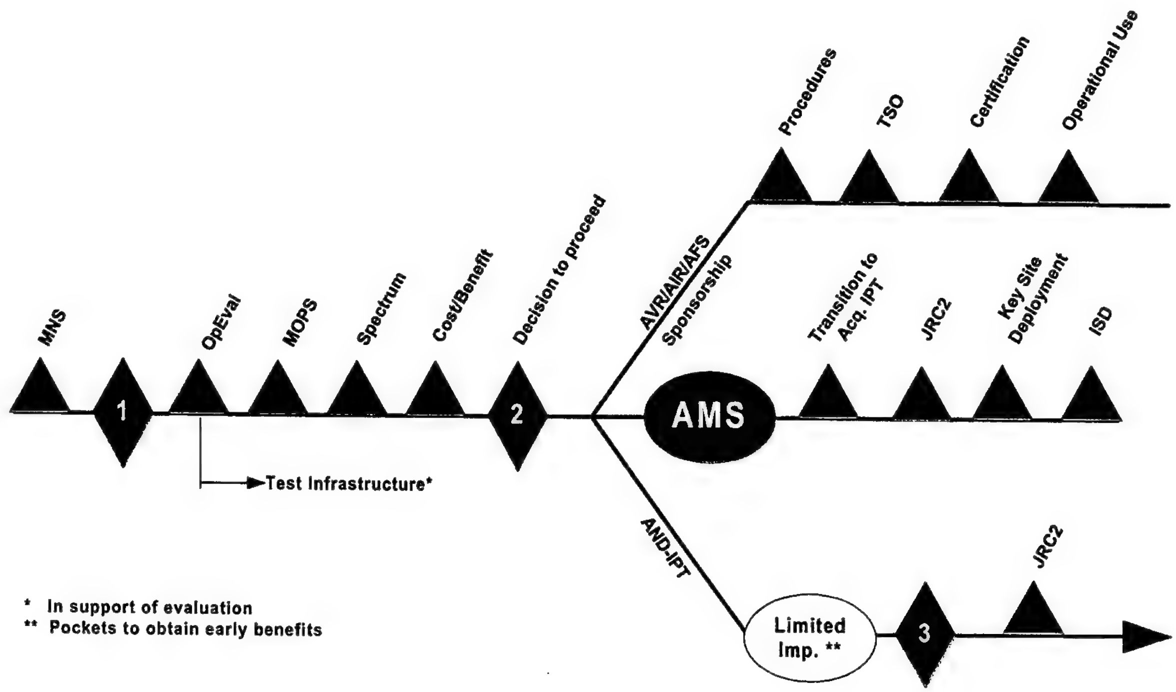


Figure 2-8. Safe Flight 21 Application Implementation Process

Section 3

Safe Flight 21 Operational Enhancements and Applications

3.1 Overview

The RTCA Select Committee was very explicit, at a high level, in their *Roadmap* document concerning the scope of evaluations that they expected in order to advance the modernization of CNS in the NAS. The Safe Flight 21 Steering Group, comprising the stakeholders interested in these enhancements, have come to a consensus on the applications that will be initially developed and evaluated to show the benefits and reduce the risk of implementing the enhancements.

The remainder of this section reiterates the nine enhancements from the Roadmap and breaks out the applications that will be evaluated. Since this is an evolving plan, a mapping to applications that have been considered in previous versions of this plan is made at the end of the section. There are applications similar to these defined, or at least alluded to, in the ADS-B MASPS, the ATS Concept of Operations for the National Airspace System in 2005, and the Government/Industry Operational Concept for the Evolution of Free Flight. The mapping at the end of this section shows those connections. The applications currently planned for evaluation by Safe Flight 21 are summarized in Table 3-1. The application description that follow include all phases within the applications.

Table 3-1. Safe Flight 21 Applications

Enhancement		Opeval Fiscal Year	Application
Weather and Other Information to the Cockpit	1.1.1	00 (AK)	Initial FIS-B based on today's availability (NEXRAD graphics, METAR/SPECI, TAFs, SIGMETs, PIREPs and sever weather forecast alerts)
	1.1.2	01 (AK)	Add products such as NOTAMs, lightning, icing, turbulence, real time SUA, and Volcanic ash
Cost Effective CFIT Avoidance	2.1	00 (AK)	Low cost terrain situational awareness
	2.2	01 (AK)	Increased access to terrain constrained low altitude airspace
Improved Terminal Operations in Low Visibility	3.1.1	99 (ORV)	Enhanced visual approaches (Visual acquisition with existing procedures, ADS-B only)
	3.1.2	00 (ORV)	Enhanced visual approaches (with new procedures using ADS-B only)
	3.1.3	01 (ORV)	Enhanced visual approaches (with new procedures using ADS-B and TIS-B)
	3.2.1	00 (ORV)	Approach spacing (for visual approaches)
	3.2.2	01 (ORV)	Approach spacing (for instrument approaches)
	3.4	00 (ORV)	Departure spacing/clearance (VMC in radar)
Enhanced See and Avoid	4.1.1	99 (ORV)	Enhanced visual acquisition of other traffic for see-and-avoid (using ADS-B only)
	4.1.2	01 (Both)	Enhanced visual acquisition of other traffic for see-and-avoid (ADS-B and TIS-B)
	4.2.1	00 (ORV)	Conflict detection
	4.2.2	02 (ORV)	Conflict resolution
Enhanced En Route Air-to-Air Operations	5.2.1	00 (AK)	Pilot situational awareness beyond visual range
Improved Surface Surveillance and Navigation for the Pilot	6.1.1	00 (Both)	Runway and final approach occupancy awareness (using ADS-B only)
	6.1.2	01 (ORV)	Runway and final approach occupancy awareness (using ADS-B and TIS-B)
	6.2	01 (Both)	Airport surface situational awareness
Enhanced Surface Surveillance for Controller	7.1	00 (ORV)	Enhance existing surface surveillance with ADS-B
	7.2	01 (ORV)	Surveillance coverage at airports without existing surface surveillance
ADS-B Surveillance in Non-Radar Airspace	8.1	00 (AK)	Center situational awareness with ADS-B
	8.2	00 (AK)	Radar-like services with ADS-B
	8.3	00 (AK)	Tower situational awareness beyond visual range
Establish ADS-B Separation Standards	9.1.1	00 (Both)	Radar augmentation with ADS-B to support mixed equipage in terminal airspace
	9.2.1	00 (Both)	Radar augmentation with ADS-B to support mixed equipage in en route airspace

(Note: Applications not evaluated in 1999 through 2002 are listed in Tables 3-3 and 3-4)

Enh. 1: Weather and Other Information to the Cockpit

This enhancement will use the Flight Information System (FIS) to receive current and forecasted weather and flight information as well as other information. The enhanced weather products will be available to pilots and controllers, allowing them to share the same situational awareness. The information will be displayed textually and graphically to the pilot.. The expected benefits are the following:

- Reduced flight times by skirting adverse weather
- Reduced flight times by exploiting available SUA
- Increased safety
- Reduced Flight Service Station workload
- More GA flight initiatives with weather information during flight
- Improvement in tactical planning for aircraft equipped with weather radar
- Improvement in tactical planning for aircraft equipped with icing and SUA graphics

App. 1.1.1 Initial FIS-B

This application will enhance pilot awareness of weather and airspace/facility status by incorporating broadcast flight information into cockpit multifunction displays. Initial (text only) products will include NEXRAD graphics, METAR and SPECI surface observations, TAFs and applicable amendments, SIGMETs and convective SIGMETs, AIRMETs, urgent and routine PIREPs, and Severe Weather Forecast Alerts.

App. 1.1.2 Additional FIS-B Products

This application will add additional exchange of aeronautical data that includes NOTAMs, lightning, icing, turbulence, real-time SUA, and volcanic ash.

Enh. 2: Cost Effective CFIT Avoidance

There have been many fatal accidents involving controlled flight into terrain (CFIT) due to poor pilot situational awareness. This enhancement will increase the pilot's situational awareness by providing a cost/effective terrain and obstacle database and integrated display in the cockpit. The expected benefits are the following:

- Reduced CFIT accidents
- Decreased pilot workload
- Increased access to low altitude routes
- Increased capability to avoid hazardous weather conditions relating to certain altitude (e.g., icing)
- Increased ability to fly at lower altitude to avoid need for IFR at higher altitude

App. 2.1 Low cost terrain situational awareness

This application will enhance pilot awareness of terrain by using on-board databases, GPS navigation, and barometric altitude to generate moving terrain maps on cockpit multifunction displays. The initial capability color-codes vertical clearance to terrain, suitable for VFR operation.

App. 2.2 Increased access to terrain constrained low altitude airspace

This application adds capabilities including obstacle data to the on-board databases and provides alert functions. This increased situational awareness may facilitate lower altitude GPS routes or lower altitude random off-airway navigation for suitably equipped aircraft.

Enh. 3: Improved Terminal Operations in Low Visibility

This enhancement will use ADS-B, CDTI and TIS-B during low visibility approach operations so that the crew will be better able to identify the aircraft to follow and accomplish approaches at lower minimums, thus maintaining VFR throughput longer. The crew will also be able to maintain better spacing during VFR and IFR approaches. The expected benefits are the following:

- Increased access to airports during marginal weather
- Reduced arrival delays
- Increased predictability of arrival & departure times
- Increased flexibility of arrival scheduling
- Increased airport capacity
- Increased safety for terminal area approaches and departures
- Increased efficiency of terminal operations
- Reduced go-arounds
- Enhance special VFR airspace access
- Decreased controller workload
- Decreased voice communications and increased voice-channel availability

App. 3.1 Enhanced visual approaches

This application helps pilots visually acquire and identify the aircraft called-out by controllers prior to visual approach clearances by showing the identity and trajectory of aircraft on a CDTI. By using the CDTI to aid in the transition to a visual approach, the procedure will be used more often and more efficiently. Visual approaches are the backbone of operations at major airports in the US and provide greater arrival capacity than IFR operations. During visual approaches, traffic advisories are issued to pilots, and once the pilot confirms acquisition of traffic and runway, a visual approach clearance is issued. Most facilities have specific established minima to which visual approaches can be conducted; however, specific environmental conditions such as haze, sun light, and patchy clouds may

result in the suspension of visual approaches at higher ceiling and visibility values. CDTI may help enhance visual approach operations in one of several ways including:

- Improved visual traffic acquisition
- Reduction in pilot and controller workload
- Increased reliability of conducting visual operations to established minima
- Reduction in the minima to which visual approaches are conducted

The first phase (3.1.1) of the application avoids significant changes to air traffic management (ATM) communication procedures by not including flight ID in traffic call-outs by controllers. This phase also avoids requiring any additional functionality in the ground automation systems by relying solely on the ADS-B of equipped aircraft for the information displayed on the CDTI.

The second phase (3.1.2) of the application extends current pilot/controller procedures for visual approaches to take explicit advantage of the positive identification of traffic that is supported by ADS-B/CDTI. The procedures for traffic call-out by the controller to a CDTI equipped aircraft will be changed to include the flight ID of the traffic. This is expected to further enhance the safety and efficiency of visual approaches.

In the third phase (3.1.3) of the application, non-equipped aircraft appear on the CDTI based on a Traffic Information Service Broadcast (TIS-B) of ground radar-based data. This makes the application more broadly usable in situations of mixed equipage. This phase of the application will address the TIS-B function in the ground automation systems and the human factors issues of presenting TIS-B targets on the CDTI.

App. 3.2 Approach spacing

This application will provide the pilot with additional cues on the CDTI regarding the dynamics of the aircraft that the pilot is following to improve safety and efficiency.

The first phase (3.2.1) of this application will additional cues on the on visual approach and guidance toward achieving a desired interval. These cues and guidance are expected to allow the pilot to make more consistent and efficient visual approaches.

The second phase (3.2.2) of this application will apply these tools (with extension if needed) for instrument approaches. Spacing near minimum radar separation standards will provide more consistent arrival intervals and higher arrival rates. The pilot will receive radar vectors from ATC to intercept the approach course, and at an appropriate time will be given a spacing interval behind the preceding arrival. At a later time, further enhancements to the CDTI may aid in optimizing protection from wake vortex induced by the lead aircraft.

App. 3.4 Departure spacing/clearance

Often minimum spacing is not obtained on departure because of controller workload, pilot response time, and/or limitations of radar surveillance. However, if the CDTI function can aid pilots in departing and maintaining spacing behind a leading aircraft, the controller may be able clear the aircraft for departure based on CDTI spacing and gain additional throughput over the departure routes.

Enh. 4: Enhanced See and Avoid

This enhancement will provide traffic information, electronically, to the cockpit using ADS-B, CDTI, and TIS-B. This will enable the pilot to maintain situational awareness of surrounding traffic. The expected benefits are the following:

- Increased safety
- Decrease in pilot/controller workload
- Resolve conflicts earlier with resulting efficiencies
- Reduce disruptions to ATC
- Increased capacity
- Increased efficiencies
- Change in tower establishment criteria

App. 4.1 Enhanced visual acquisition of other traffic for see-and-avoid

This application provides a display of nearby traffic on the CDTI to help the pilot see-and-avoid traffic. If traffic is sighted, the pilot must first assess the threat posed by the nearby aircraft then, if necessary, maneuver to avoid the other aircraft. The effectiveness of see-and-avoid depends on the ability of a pilot to visually acquire the nearby aircraft early enough in the encounter to enable threat assessment and avoidance.

The first phase (4.1.1) of this application will be to evaluate see-and-avoid using only ADS-B/CDTI. This will show nearby aircraft that are equipped with ADS-B.

The second phase (4.1.2) of this application extends the CDTI by displaying non-equipped aircraft which are detected by ATC radar and transmitted to the CDTI using TIS-B. In areas with significant numbers of aircraft that are not ADS-B equipped, the effectiveness of using CDTI based on ADS-B only for acquisition of traffic would be limited. With TIS-B information, the identity, position and estimated ground speed of the other traffic that are known to the controller will be supplied to the pilot. This will assist equipped pilots by providing a display of all nearby traffic within the TIS-B supported area. This phase of the application will address the TIS-B function in the ground automation systems and the human-factors issues of presenting TIS-B targets on the CDTI.

App. 4.2.1 Conflict Detection

This application alerts pilots to potential conflicts with other aircraft, thereby facilitating timely action (if necessary) to prevent or end the conflict This application will address human factors and algorithm issues such as false alerts, the relationship to TCAS alerts, and indirect impacts on ATC operations.

App. 4.2.2 Conflict Resolution

This application advises the pilot of a maneuver to resolve the previously detected conflict. This application will address human factors and algorithm issues and will address potential interactions with TCAS on one or both aircraft.

Enh. 5: Enhanced En Route Air-to-Air Operations

This enhancement will evaluate use of CDTI and ADS-B to allow delegation of separation authority to the cockpit, resulting in increased efficiency. The expected benefits are the following:

- Increased en route capacity
- Increased fuel efficiency
- Increased pilot flexibility
- Decreased controller workload
- Increased throughput for "one-in/one-out" airspace

App. 5.2.1 Pilot situational awareness beyond visual range

This application extends pilot situational awareness of traffic that is beyond visual range by including distant traffic and airspace boundaries on the cockpit multi-function display. The application is intended to aid pilot-pilot coordination in VFR, SVFR and night operations by showing the overall multiple-aircraft pattern of operations in the airspace rather than only those aircraft that are closest and within visual range. Air-to-air ADS-B messages will identify and give the trajectory of ADS-B equipped aircraft. Ground-to-air TIS-B messages will identify and give the trajectory of non-equipped aircraft that are in radar surveillance. Airspace boundaries will be presented from an on-board database.

Enh. 6: Improved Surface Surveillance and Navigation for the Pilot

This enhancement will be designed to allow pilots in the cockpit and the operators of equipped vehicles on the airport surface to "see" all the other traffic on a display with a moving map, resulting in safer and more efficient surface operations. Also, aircraft will be able to taxi using augmented GPS navigation and maps and in extremely low visibility conditions using LAAS. The expected benefits are the following:

- Increased safety during surface movements
- Increased safety during approaches, landings and take-offs
- Reduced taxi times
- Increased predictability of taxi times
- Increased airport capacity (aircraft operations)
- Improved efficiency of gate management operations
- Improved surface operations (all surface operations)
- Improved airport surface operation in IMC conditions
- Reduced surface controller workload

App. 6.1 Runway and final approach occupancy awareness

This application provides pilots on final approach and on the runway with awareness of other aircraft that are on or approaching the runway.

The initial phase (6.1.1) of this application provides awareness only of equipped aircraft and/or vehicles, and will be of benefit primarily in situations where all or nearly all aircraft/vehicles are equipped. Evaluation will initially be based on the capabilities of un-augmented GPS and basic CDTI, but augmented GPS or limited CDTI enhancements may be found necessary.

The second phase (6.1.2) increases the value of the application by including non-ADS-B-equipped aircraft on the CDTI. The ADS-B data on the CDTI is augmented with TIS-B data from ground-based terminal and surface radar and multilateration techniques. This will provide the pilot of equipped aircraft with information on equipped and non-equipped aircraft, vehicles, and obstructions.

App. 6.2 Airport surface situational awareness

This application enhances the pilot's visual situational awareness by displaying an airport map with aircraft, vehicle, and obstacle positions based on ADS-B (and possibly TIS-B). GPS augmentation with WAAS is expected to be necessary (and adequate) for this application.

Enh. 7: Enhanced Airport Surface Surveillance for the Controller

This enhancement will equip the aircraft and ground vehicles in the airport movement area with ADS-B using augmented GPS-derived positions. The local and ground controllers in the tower will monitor the position and speeds of all the traffic in the movement area. The expected benefits are the following:

- Increased safety during surface movements
- Increased safety during landings and take-offs
- Reduced taxi times

- Increased predictability of taxi times
- Increased airport capacity (aircraft operations)
- Improved efficiency of gate management operations
- Reduction in emergency response time
- Improved surface operations (all surface operations)
- Reduced rate of pilot/air traffic control communications

App. 7.1 Enhance existing surface surveillance with ADS-B

This application integrates the position, identification, and speed of all equipped ADS-B aircraft with existing surface surveillance to fill the gaps in the existing coverage. The local and ground controllers in the tower could then monitor the position and speeds of all the equipped aircraft.

App. 7.2 Surveillance coverage at airports without existing surface surveillance

This application uses ADS-B and multilateration of other radar returns to provide surface surveillance capabilities at airports without existing surface surveillance. This would increase safety monitoring, enhance crash, fire, and rescue capabilities, as well as improve ground ATC operations.

Enh. 8: ADS-B for Surveillance in Non-Radar Airspace

This enhancement will use ADS-B to provide additional surveillance coverage and fill gaps in today's radar coverage. The expected benefits are the following:

- Increased capacity in airports and airspace
- Reduced separation minima in comparison to procedural separation
- Increased flexibility in route flown
- Increased safety
- Increased efficiency in aircraft operations
- Increased predictability of flight times
- Reduced flight delays

App. 8.1 Center situational awareness with ADS-B

This application provides center controllers with enhanced situational awareness of traffic in non-radar airspace by identifying ADS-B equipped aircraft and their trajectories on a controller display. This will aid the controller in providing procedural separation and other non-radar services and in coordinating with the tower controller on airspace changeovers between IFR en route operations and terminal area SVFR operations.

Potential uses of ADS-B to aid search and rescue and for communicating aircraft emergency conditions to the controller are being considered for inclusion in this application.

App. 8.2 Radar-like services with ADS-B

This application provides terminal area controllers of non-radar airspace with surveillance, conflict alert and MSAW that are based on ADS-B, to enable provision of radar-like services to VFR and IFR aircraft. This includes emergency services, separation, sequencing, traffic and terrain advisories, navigational assistance, and route optimization. Aircraft not providing ADS-B are handled similarly to aircraft without a transponder in secondary radar airspace.

App. 8.3 Tower situational awareness beyond visual range

This application extends the tower cab controller situational awareness of traffic that is beyond visual range by using ADS-B to identify aircraft and their trajectories on a tower display. This application is intended for VFR, SVFR and night operations and will aid tower-pilot and tower-center coordination by showing the over-all multiple-aircraft pattern of operations in the airspace rather than only those aircraft that are nearest the tower and within visual range. In SVFR operations this will also help the tower controller coordinate with the center controller on airspace changeovers between SVFR and IFR operations.

Enh. 9: Establish ADS-B Separation Standards

Current automation is limited in providing benefits to users based on existing radar accuracy. This enhancement will integrate ADS-B data with radar and conflict alert automation to determine if today's separation standards can be achieved or reduced. Ultimately ADS-B will be integrated with advanced decision support automation. The expected benefits are the following:

- Better controller awareness of equipped traffic actual positions
- Improved ability for radar automation systems to estimate aircraft trajectories (e.g., conflict alert, minimum safe altitude warning)
- Higher surveillance system availability
- More efficient application of separation standards
- More accurate traffic advisories by controller to pilots

App. 9.1.1 Radar augmentation with ADS-to support mixed equipage in terminal airspace

This application integrates ADS-B data with radar data to increase the accuracy and availability of multi-sensor surveillance information in the terminal airspace. Air-to-ground ADS-B messages will contribute to the identification and tracking of ADS-B equipped aircraft when data from multiple sensors is processed for display to the controller. ADS-B will also provide a back-up to radar sensors in the event of sensor outage. This application will evaluate the ADS-B accuracy, integrity, and availability for provision of radar-like services as well as the procedures that deal with mixed equipage airspace.

App. 9.2.1 Radar augmentation with ADS-B to support mixed equipage in en route airspace

This application integrates ADS-B data with radar data to increase the accuracy and availability of multi-sensor surveillance information in the en route airspace. Air-to-ground ADS-B messages will contribute to the identification and tracking of ADS-B equipped aircraft when data from multiple sensors is processed for display to the controller. ADS-B will also provide a back-up to radar sensors in the event of sensor outage. This application will evaluate the ADS-B accuracy, integrity, and availability for provision of radar-like services as well as the procedures that deal with mixed equipage airspace.

3.2 Application Traceability

3.2.1 Current Applications

The applications listed above have evolved since the August 1998 *Roadmap* was completed. In the process of identifying stakeholders who will support the evaluation of the applications and resources necessary to support the applications within the next two years, the applications were prioritized and some of the applications were dropped from the list. Section 4 of this Master Plan will go into the details of the current application priorities. These applications have a history related to the Government/Industry Operational Concept, the Air Traffic Concept of Operations, and RTCA's ADS-B MASPS. Table 3-2 summarizes all the Safe Flight 21 applications and traceability.

3.2.2 Previous Applications Not Evaluated by 2002

There are several reasons why an application will not be evaluated by the Safe Flight 21 program. One of those reasons is that, due to resource constraints, the application cannot be evaluated until after 2002. For example, applications 6.3 and 9.3 are important to the stakeholders but fell outside of the Safe Flight 21 program plan to evaluate the applications between FY99 and FY02. These applications are listed in Table 3-3.

3.2.1 Previous Application Eliminated

The remainder of the applications the stakeholders view as not as important to them as the previous applications. The issues involved with application 3.3 (Enhanced parallel approaches in VMC/MVMC) are addressed to some degree in applications 3.1 and 3.2 (Enhanced visual approaches and final approach spacing). Application 4.2 is really a combination of the other 4.x applications. Applications 5.1, 5.3, 5.4, and 5.5 are of marginal short-term benefit except in oceanic airspace which is outside the scope of Safe Flight 21. These applications are summarized in Table 3-4.

Table 3-2. Current Application Traceability

	MP 1.0.5 App #	Ohio Valley Importance	Capstone Importance	ADS-B MASPS	Joint ConOps	AT ConOps
1.1.1 Initial FIS-B (with NEXRAD graphics, METAR, SPECI, TAFs, SIGMETs, AIRMETs, PIREPs and Severe Weather Forecast Alerts)	1.1.1		9		3.1, 3.1.1, 3.2, 3.2.2, 3.3, 4.1, 4.1.3, 4.2, 4.3.3, 5.1, 5.1,2, 5.2	1.3, 4, 4.2.1
1.1.2 Addtional FIS-B products (NOTAMs, lightning, icing, turbulence, real-time SUA and volcanic ash)	1.1.2		9			
2.1 Low cost terrain situational awareness	2.1		10		4.1, 4.1.2, 5.1, 5.1.2, 5.2.2	
2.2 Increased access to terrain constrained low altitude airspace	2.2		9		5.2.2	
3.1.1 Enhanced visual approaches (ADS-B only, no new procedures)	3.1.1	9		D.1.10	4.1, 4.1.1	4.1
3.1.2 Enhanced visual approaches (ADS-B only, new procedures)	3.1.2	9				

	MP 1.0.5 App #	Ohio Valley Importance	Capstone Importance	ADS-B MASPS	Joint ConOps	AT ConOps
3.1.3 Enhanced visual approaches (ADS-B and TIS-B, new procedures)	3.1.3	6				
3.2.1 Approach spacing (Visual Approaches)	3.2	9		D.1.11	4.1, 4.1.1	4.1
3.2.2 Approach spacing (Instrument Approaches)	3.2	9			4.1, 4.1.1, 4.2.1	4.1, 4.2.1
3.4 Departure spacing/clearance (VMC in radar)	3.4	8		D.1.12	4.1, 4.1.1	
4.1.1 Enhanced visual acquisition of other traffic for see-and-avoid (ADS-B only)	4.1.1	7		D.1.15 D.1.19	4.1, 4.2, 4.2.1, 5.1.1, 5.1.2, 5.1.3, 5.2, 5.2.2	4.1
4.1.2 Enhanced visual acquisition of other traffic for see-and-avoid (ADS-B and TIS-B)	4.1.2	6				3.2.2, 4.1
4.2.1 Conflict Detection and Resolution (Conflict Detection)	4.3.1	10		D.1.21	4.2.1, 5.2	

	MP 1.0.5 App #	Ohio Valley Importance	Capstone Importance	ADS-B MASPS	Joint ConOps	AT ConOps
4.2.2 Conflict Detection and Resolution (Conflict Resolution)	4.3.2	10		D.1.22		
5.2.1 Pilot situational awareness beyond visual range	5.2		9	D.1.15 D.1.20	4.2, 5.2	
6.1.1 Runway and final approach occupancy awareness (ADS-B only)	6.1.1	8		D.1.16	3.1	
6.1.2 Runway and final approach occupancy awareness (ADS-B and TIS-B)	6.1.2	6		D.1.16	3.1	
6.2 Airport surface situational awareness	6.2	8	7	D.1.17	3.1, 3.2	
7.1 Enhance existing surface surveillance with ADS-B	7.1	8			3.2, 3.3	
7.2 Surveillance coverage at airports without existing surface surveillance	7.2	8		D2.11	3.2	
8.1 Center situational awareness with ADS-B	8.1		9+	D.2.1 D.2.2	5.2	5.1

	MP 1.0.5 App #	Ohio Valley Importance	Capstone Importance	ADS-B MASPS	Joint ConOps	AT ConOps
8.2 Radar-like services with ADS-B	8.2		9+	D.2.3		
8.3 Tower situational awareness beyond visual range			8	D.2.1	4.2	
9.1.1 Radar augmentation with ADS-B to support mixed equipage in terminal airspace	9.1 & 9.2	9	9	D.2.4 D.2.7	4.1, 4.2, 4.3, 5.2	4.2.1, 5
9.2.1 Radar augmentation with ADS-B to support mixed equipage in en route airspace	9.1 & 9.2	9	9	D.2.4 D.2.7	4.1, 4.2, 4.3, 5.2	4.2.1, 5

Table 3-3. Traceability of Previous Applications Not Evaluatable by 2002

		MP 1.0.5 App #	Ohio Valley Importance	Capstone Importance	ADS-B MASPS	Joint ConOps	AT ConOps
3.5	Approaches to closely spaced parallel runways	--			D.1.14		
5.2.2	Extended see and avoid for one-in, one-out airspace	5.2			D.1.4		
6.3	Enhanced IMC airport surface operations	6.3	5		D.1.18	3.2, 3.3, 3.3.1	
9.1.2	Radar augmentation with ADS-B to achieve existing separation standards in terminal airspace						
9.2.2	Radar augmentation with ADS-B to achieve existing separation standards in terminal airspace						
9.3	Reduced separation standards with ADS-B	9.1 & 9.2	5		D.2.4 D.2.7	4.2, 5.2	

Table 3-4. Traceability of Previous Applications Not Carried Forward

	MP 1.0.5 App #	Ohio Valley Importance	Capstone Importance	ADS-B MASPS	Joint ConOps	AT ConOps
Enhanced parallel approaches in VMC/MVMC	3.3				4.2.1	
Traffic situational Awareness in domestic airspace	4.2			D.1.20	4.1, 4.2, 4.2.1, 5.1.1, 5.1.2, 5.1.3, 5.2, 5.2.2	4.1
Closer climb & descent in non-radar airspace	5.1		4	D.1.1 D.1.2	†	†
In-trail spacing in en route airspace	5.3			D.1.5	5.1	
Merging in en route airspace	5.4			D.1.7	5.1.1	†
Passing Maneuvers in en route airspace	5.5			D.1.3 D.1.8	†	

† References to these types of operations in the Joint and Air Traffic ConOps are only in the oceanic section which is not covered by the *Roadmap*.

Section 4

Safe Flight 21 Multiyear Plan

4.1 Planning Process

4.1.1 Planning Concepts

The Safe Flight 21 planning process takes an iterative approach because it is difficult to determine in advance the operational concepts that will deliver the most user benefit or to anticipate all the complexities that will need to be resolved before they can be fully evaluated. This process is risk driven and supports the evolution of functional and performance requirements rather than assuming all requirements can be fully known in advance.

Figure 4-1 illustrates the basic concepts of the Safe Flight 21 process, the activities leading up to the formation of the Safe Flight 21 program and the current cycle of the plan. The first activity in a cycle is to examine the environment to identify the stakeholders, the objectives, the known major constraints and the alternatives to meeting the program objectives. This is accomplished in the "Understand the Context" part of the spiral. Then the risks of the alternatives are analyzed and a direction for the program is determined. The next segment, the plan for the cycle is developed. This is followed by the actual development of products. In the case of Safe Flight 21, the products are development, demonstrations and evaluations. After the work on the cycle is completed the planning of future cycles in the spiral is revised using the information gained.

Since achievement of the primary objective of the program requires working with the stakeholders and maintaining a consensus with the stakeholders, the natural duration of the cycles within the spiral should correspond to gaining stakeholder approval and consensus for the program. The top-level coordinating body for stakeholders in Safe Flight 21 is the RTCA Free Flight Steering Committee which is the cognizant Federal Advisory Committee for CNS/ATM modernization for the FAA and includes industry, labor, user and FAA representatives. The Free Flight Steering Committee meets three times per year. Safe Flight 21 cycles are timed to the FFSC's fall meetings.

Past events that have led up to the creation of the Safe Flight 21 program can be interpreted in terms of the cycle segments as shown in Figure 4-1. The NAS Modernization Task Force (NMTF) identified and assessed the risks of the NAS Modernization programs. This task force particularly assessed the risks of the Communication, Navigation and Surveillance (CNS) programs as high, leading to a recommendation for the FAA to work with industry to

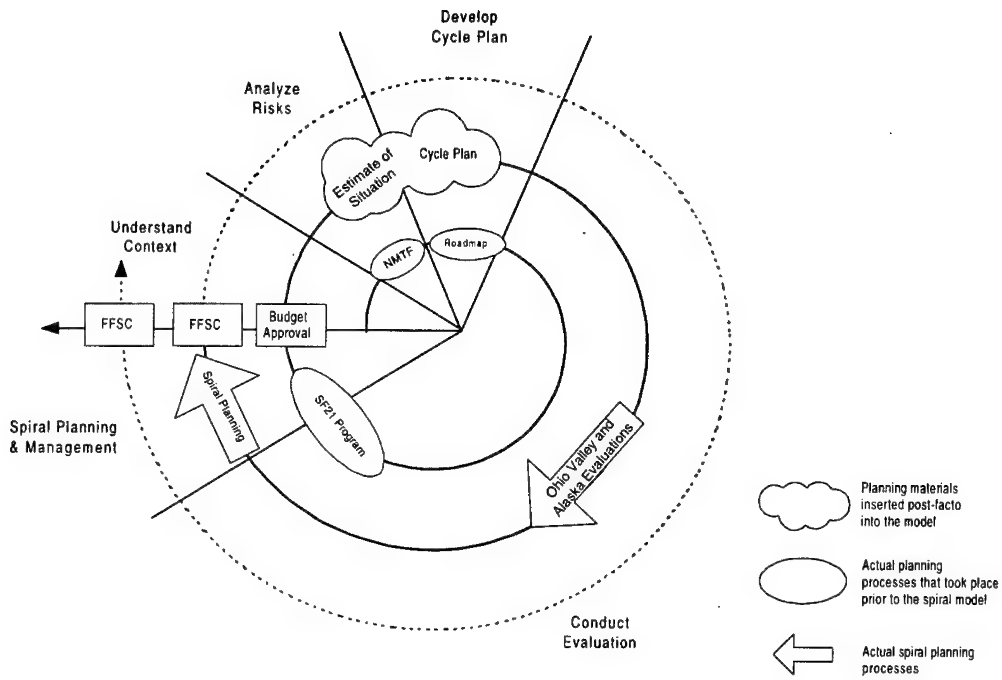


Figure 4-1. The Safe Flight 21 Planning Process

reduce these risks. The FFSC directed that the RTCA Select Committee (which supports it) develop a roadmap to guide development of CNS enhancements needed for Free Flight. With endorsement by the stakeholders and funding by Congress, the roadmap led to the formation of the Safe Flight 21 Program.

At the time the program was being formed, the Cargo Airlines Association (CAA) was well on its way to defining its demonstration and evaluation process in the Ohio Valley. At the same time, the Alaskan Region Industry Council was defining its Capstone Project. Both of these activities address enhancements called for in the roadmap and both are now associated with and supported by Safe Flight 21.

Central to the spiral planning process of Safe Flight 21 is the extension of incremental stakeholder consensus and buy-in. With each cycle of the spiral, shared understanding should be gained and commitment to the Safe Flight 21 process reinforced through small but ongoing wins in the iterative definition, development, and evaluation of the enhancements. New knowledge, with accompanying adjustments in stakeholder priorities and commitment, will cause revisions to the spiral plan and guide the definition of successive cycle plans. These occur with the oversight and participation of the stakeholders.

An "unrolled" version of the current Safe Flight 21 spiral is shown in Figure 4-2.

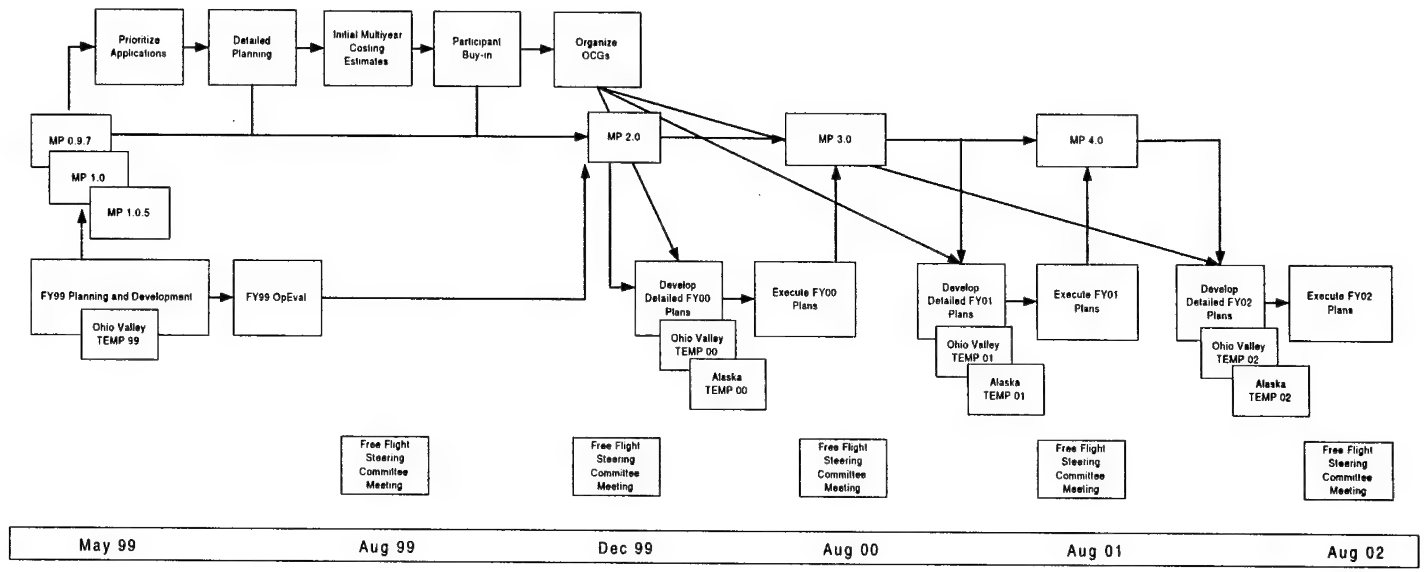


Figure 4-2. Multiyear Planning Cycle[7]

7 In some instances, detailed planning documents such as TEMPs may span fiscal year boundaries or include multiple years.

4.1.2 Scheduling Process

The multiyear schedule for evaluating the Safe Flight 21 enhancements is being developed collaboratively by the FAA, industry and users. It was recognized early in the program that budget and other factors would constrain the rate at which the enhancements could be evaluated. The Safe Flight 21 Steering Group in coordination with other stakeholders and participants has prioritized the applications within the nine enhancements and established a target schedule for their evaluation and initial implementation. (The schedule achieved will depend on the complexity and resource requirements of developing and evaluating the applications, which will be better known as more detailed plans are developed and as results from early activities are learned.)

This subsection describes the process by which the target schedule was established.

4.1.2.1 Analysis

Characterizing the Safe Flight 21 Development and Evaluation Process

RTCA SC-186 developed and published a "template" (checklist) of processes associated with the development, evaluation, and implementation of applications that require new CNS technology and avionics. From this "template" and from experiences developing other CNS-based applications, a more detailed series of generic activities for Safe Flight 21 applications was proposed. These are listed in Table 4-1, and described in Appendix A. Each activity in the list below has been annotated with the Safe Flight 21-related organizations expected to take responsibility for it. Whether all of these activities or additional activities not in the checklist are needed will vary from application to application, as will the details and level of effort of the activities. Nevertheless, this generic characterization of the path towards implementation provides insight into the rough schedule that can be anticipated from previous efforts, and provides a starting point for developing actual plans specific to each enhancement application.

Figure 4-3 shows a generic multi-year time sequence for completion of these activities that is based on experiences with other CNS-based avionics-centered applications. As with the activities themselves, actual overall schedules will depend on the specifics of the enhancement application, and will be better determined (as Safe Flight 21 progresses) through more specific detailed planning and from the results of activities as they are completed. Nevertheless, the generic schedule can be used to estimate timeframes for development and evaluation of new applications.

Table 4-1. Development, Evaluation and Implementation Tasks for Safe Flight 21 Applications with Responsible Organization or Activity

1. Operational Concept

1.1	Define operational concept	O/PSG
1.2	System Functionality	P&S

2. Benefits and Constraints

2.1	Cost/Benefit Estimates and Parameters	C/BSG
2.2	Quantitative Costs and Benefits	C/BSG
2.3	Cumulative Implementation Cases	C/BSG
2.4	Investment Decisions and Deployment Consensus	(FAA/Users/Ind.)

3. Maturity of Concept and Technology

3.1	Looks Feasible and Worth Developing?	SFStG

4. Operational Procedures

4.1	Initial Definition of Procedures	COG or OCG
4.2	Cockpit Simulation	COG or OCG
4.3	Controller Simulations	COG or OCG
4.4	Procedure Parameters	COG or OCG
4.5	Procedures Training	COG or OCG
4.6	Procedures Post-Full-Sim	COG or OCG
4.7	Procedure Post-OpEval	COG or OCG

5. Human Factors Issues (Pilot, Controller, Other)

5.1	Task Analysis	COG or OCG
5.2	Initial Cockpit Human Factors	COG or OCG
5.3	Initial Controller Human Factors	COG or OCG
5.4	Human Factors Post-Full-Sim	COG or OCG
5.5	Human Factors Post-OpEval	COG or OCG

6. End-to-End Performance and Technical Requirements

6.1	Initial Performance Estimates	P&S
6.2	Performance Requirements	T/CSG
6.3	Supportability Requirements	FAA/Users/Ind.
6.4	Performance Validation	T/CSG

7. Interoperability Requirements for Air and Ground Systems

7.1 Interoperability Analysis	P&S
7.2 Interface Requirements Documents	COG or OCG
7.3 Interoperable Prototypes	COG or OCG
7.4 Interoperability Post-OpEval	COG or OCG

8. Operational Safety Assessment

8.1 Rationale/Prelim Model	Safety
8.2 Validate Rationale/Prelim Model	Safety
8.3 Full Collision Risk Model	Safety

9. Avionics and Ground Systems

9.1 Systems and Avionics for OpEval	COG or OCG
9.2 Systems and Avionics for Certification and Approval	FAA/Industry

10. Operational Test and evaluation

10.1 Limited Data Collection	COG or OCG
10.2 Full Mission Simulation	COG or OCG
10.3 Plans for OpEval	COG or OCG
10.4 Operational Test and Evaluation	COG or OCG

11. Equipment Certification (Aircraft and Ground Systems)

11.1 Develop a Certification Issues Paper	FAA/Industry
11.2 Develop Certification Plan	FAA/Industry

12. Operational Approval (Flight Standards and Air Traffic)

12.1 Develop Issues and Resolutions Document	FAA/Industry
12.2 Document Operational Regulations	FAA/Industry
12.3 Document the Human Factors Design Criteria and Guidelines	FAA/Industry
12.4 Document Air Carrier Operator Approvals and Authorizations	FAA/Industry
12.5 Document Approved Operational Data	FAA/Industry
12.6 Produce Approved Training Program Module	FAA/Industry
12.7 Develop Operations Manuals	FAA/Industry
12.8 Develop Operational Specification	FAA/Industry
12.9 Develop General Aviation Guidance Material	FAA/Industry
12.10 Document Validation and Proving Runs	FAA/Industry
12.11 Document Post Operational Approval/Certification Activities	FAA/Industry

13. Implementation Transition

13.1 Procedure In Service	FAA/Industry
13.2 Benefits In Service	FAA/Industry
13.3 Human Factors In Service	FAA/Industry
13.4 Performance In Service	FAA/Industry
13.5 Interoperability In Service	FAA/Industry

Task Category	Concept Definition OpEval Year -2	Technical Evaluation OpEval Year -1	Operational Evaluation OpEval Year	Decision Making OpEval Year +1	Implementation
1 Operational Concept	1.1 Define Operational Concept 1.2 System Functionality				
2 Benefits & Constraints	2.1 Cost/Benefit Estimates, Params	2.2 Quantitative Costs and Benefits	2.3 Cumulative Implementation Cases	2.4 Investment Decisions and Deployment Consensus	
3 Maturity of Concepts & Technology	3.1 Looks Feasible and Worth Doing?				
4 Operational Procedures	4.1 Initial Def. of Procedures 4.2 Cockpit Simulation 4.3 Controller Simulations	4.4 Procedure Parameters 4.5 Procedures Training	4.6 Procedures Post-Full-Sim 4.7 Procedures Post-OpEval		
5 Human Factors Issues (Pilot, Controller, Other)	5.1 Task Analysis 5.2 Initial Cockpit HF 5.3 Initial Controller HF		5.4 HF Post-Full-Sim 5.5 HF Post-OpEval		
6 End to End Performance & Tech Reqs	6.1 Initial Performance Estimates	6.2 Performance Reqts 6.3 Supportability Reqts	6.4 Performance Validation		
7 Interoperability Reqs for Air and Ground Systems	7.1 Interoperability Analysis	7.2 Interface Reqts Docs	7.3 Interoperable Prototypes 7.4 Interop Post-OpEval		
8 Operational Safety Assessment		8.1 Rationale / Prelim Model	8.2 Validate Rationale / Model	8.3 Full Collision Risk Model	
9 Avionics and Ground Systems			9.1 Systems & Avionics for OpEval	9.2 Systems & Avionics for Certification and Approval	
10 Operational Test and Evaluation		10.1 Limited Data Collection	10.2 Full Mission Simulation 10.3 Plans for Op Evals 10.4 Operational Test and Evaluation		
11 Equipment Certiciation (Avionics and Ground Systems			11.1 Develop a Certification Issues Paper	11.2 Develop a Certification Plan	11.3 Deploy and Certify Equipment for Operational Use
12 Operational Approval (Flight Standards and Air Traffic)				12.1 Document Operational Regulations and Approved Data 12 2 Develop Operational Specifications and Manuals	12.3 Produce Approved Traiing Program Module 12.4 Develop General Aviation Guidance Material 12.5 Document Air Carrier Op Approvals and Authorizations 12 6 Document Validation and Proving Runs 12.7 Document Post-Op Approval/Certification Activities
13 Implementation Transition					13.1 Implement Procedures in Service 13.2 Evaluate Benefits in Service 13 3 Validate Human Factors in Service 13.4 Validate Performance in Service

Figure 4-3. Generic Task Schedule

Many of the Safe Flight 21 applications will require some level of ground infrastructure (automation system, sensor network, interfacility communications, etc) modifications or will require new NAS equipment (ground transceivers, servers, data fusion devices, etc) to be installed. This will also have to be factored into the plans to implement the applications so that time and resources can be identified within the NAS architecture, the Capital Improvement Plan and the FAA budget planning process.

The generic schedule can be used with status information on activities that have been completed or are underway to provide estimates of the likely timeframe needed for further development and evaluation before an application will be ready for operational evaluation or implementation. This method was used to provide initial input to the Safe Flight 21 Steering Group on development and evaluation lead times. Table 4-2 indicates the year in which each activity (column) for each application (row) should be completed based on current Safe Flight 21 Steering Group targets and the generic schedule. Activities that should be completed by the present time are color coded with their status: Green if the activity is complete, Yellow if it is in progress, and Red if it is not yet underway. The limitations of this generic-based analysis mean that a red code is not necessarily a true problem, only that it should be evaluated further as more detailed and specific plans are completed.

Table 4-2. Generic Application Tasks Schedule

Tasks Status 1/00

- = Completed
- = Underway
- = Not Yet Begun
- [ ] = Not Needed
- [Yr] = Year Needed

	OpEval Target	Operational Concept		Benefits & Constraints				Achievable ?	Operational Procedures							Human Factors					End to End Performance & Tech Reqs				Interoperability Req for Air and Ground Systems				Operational Safety Assessment			Avionics and Gnd Systems		Operational Test and Evaluation			
Generic Task (see Appendix A) =>		1.1	1.2	2.1	2.2	2.3	2.4	3.1	4.1	4.2	4.3	4.4	4.5	4.6	4.7	5.1	5.2	5.3	5.4	5.5	6.1	6.2	6.3	6.4	7.1	7.2	7.3	7.4	8.1	8.2	8.3	9.1	9.2	10.1	10.2	10.3	10.4
Generic Timing: Years from OpEval =>		-2	-2	-2	-1	0	1	-2	-2	-2	-2	-1	-1	0	0	-2	-2	-2	0	0	-2	-1	-1	0	-2	-1	0	0	-1	0	1	0	1	-1	0	0	0
1.1.1 Initial FIS-B (with available products)	2000	99	99	99	99	00	01	99	99				99	00	00		99		00	00	99	99	99	00	99	99	00	00		00	01	00	01	99		00	00
1.1.2 FIS-B (with additional products)	2001	99		99	00	01	02	99				00	00	01	01				01	01	99	00	00	01	99	00	01	01	00	01	02	01	02	00		01	01
2.1 Low cost terrain situational awareness	2000	99	99	99	99	00	01	99	99				99	00	00		99		00	00	99	99	99	00	99		00	00		00	01	00	01	99		00	00
2.2 Increased access / low altitude airspace	2001	99		99	00	01	02	99				00	00	01	01				01	01	99	00	00	01	99	00	01	01	00	01	02	01	02	00	01	01	01
3.1.1 Enhanced Visual Approach (ADS-B only)	1999	99	99	99	99	99	00	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	00	99	00	99	99	99	99
3.1.2 Enh. Visual Approach (ID / ADS-B only)	2000	99	99	99	99	00	01	99	99	99	99		99	00	00	99	99	99	00	00	99	99	99	00	99		00	00	99	00	01	00	01	99	00	00	00
3.1.3 Enh Visual Approach (ID / ADS-B / TIS-B)	2001	99		99	00	01	02	99	99	99	99	00	00	01	01	99		99	01	01		00	00	01		00	01	01	00	01	02	01	02	00	01	01	01
3.2.1 Approach Spacing (Visual)	2000	99	99	99	99	00	01	99	99	99	99			00	00				00	00	99	99	99	00	99		00	00	99	00	01	00	01	99	00	00	00
3.2.2 Approach Spacing (Instrument)	2001	99	99	99	00	01	02	99	99	99	99	00	00	01	01				01	01	99	00	00	01	99	00	01	01	00	01	02	01	02	00	01	01	01
3.4 Departure Spacing (VMC)	2000	99	99	99	99	00	01	99	99					00	00				00	00	99	99	99	00	99		00	00	99	00	01	00	01		00	00	00
4.1.1 See-And-Avoid (ADS-B only)	1999	99	99	99	99	99	00	99	99	99		99	99	99	99	99	99		99	99	99	99	99	99	99	99	99	99	99	99	00	99	00	99	99	99	99
4.1.2 See-And-Avoid (ADS-B / TIS-B)	2001	99		99	00	01	02	99	99			00	00	01	01	99	99		01	01		00	00	01		00	01	01	00	01	02	01	02	00	01	01	01
4.2.1 Conflict Detection	2000	99	99	99	99	00	01	99	99					00	00	99			00	00	99	99	99	00			00	00	99	00	01	00	01	99	00	00	00
4.2.2 Conflict Resolution	2003	01	01	01	02	03	04	01	01	01	01	02	02	03	03	01	01	01	03	03	01	02	02	03	01	02	03	03	02	03	04	03	04	02	03	03	03
5.2.1 Pilot Sit. Aware. Beyond Vis Range	2000	99	99	99	99	00	01	99	99			99	99	00	00		99		00	00	99	99	99	00			00	00	99	00	01	00	01	99	00	00	00
6.1.1 Runway / Final Occupancy (ADS-B only)	2000	99	99	99	99	00	01	99	99	99				00	00	99	99		00	00	99	99	99	00			00	00	99	00	01	00	01	99	00	00	00
6.1.2 Runway / Final Occupancy (ADS-B / TIS-B)	2001	99	99	99	00	01	02	99	99			00	00	01	01	99	99		01	01	99	00	00	01	99	00	01	01	00	01	02	01	02	00	01	01	01
6.2 Airport Surface Situational Awareness	2001	99	99	99	00	01	02	99	99	99		00	00	01	01	99	99		01	01	99	00	00	01	99	00	01	01	00	01	02	01	02	00	01	01	01
7.1 Enhanced Surface Surv. for Controller	2000	99	99	99	99	00	01	99	99		99	99		00	00	99		99	00	00	99	99	99	00	99	99	00	00	99	00	01	00	01	99	00	00	00
7.2 Surveillance without ASDE	2001	99	99	99	00	01	02	99	99		99	00	00	01	01	99		99	01	01	99	00	00	01	99	00	01	01	00	01	02	01	02	00	01	01	01
8.1 Center Situational Awareness	2000	99	99	99	99	00	01	99	99		99		99	00	00	99		99	00	00	99	99	99	00	99	99	00	00	99	00	01	00	01	99	00	00	00
8.2 Radar-Like Services with ADS-B	2000	99	99	99	99	00	01	99	99		99	99	99	00	00	99		99	00	00	99	99	99	00	99	99	00	00	99	00	01	00	01	99	00	00	00
8.3 Tower Sit. Aware. Beyond Visual Range	2000	99	99	99	99	00	01	99	99		99		99	00	00	99		99	00	00	99	99	99	00	99	99	00	00	99	00	01	00	01	99	00	00	00
9.1 ADS-B Enhancement of en Route Radar	2000	99	99	99	99	00	01	99	99					00	00	99		99	00	00	99	99	99	00	99	99	00	00	99	00	01	00	01	99	00	00	00
9.2 ADS-B Enhancement of Terminal Radar	2000	99	99	99	99	00	01	99	99					00	00	99			00	00	99	99	99	00	99	99	00	00	99	00	01	00	01	99	00	00	00

Dependencies between Applications

The sequence in which the Safe Flight 21 applications can be operationally evaluated is partially constrained by the dependencies of more complex applications that build upon simpler ones. These dependencies are diagrammed in Figure 4-4.

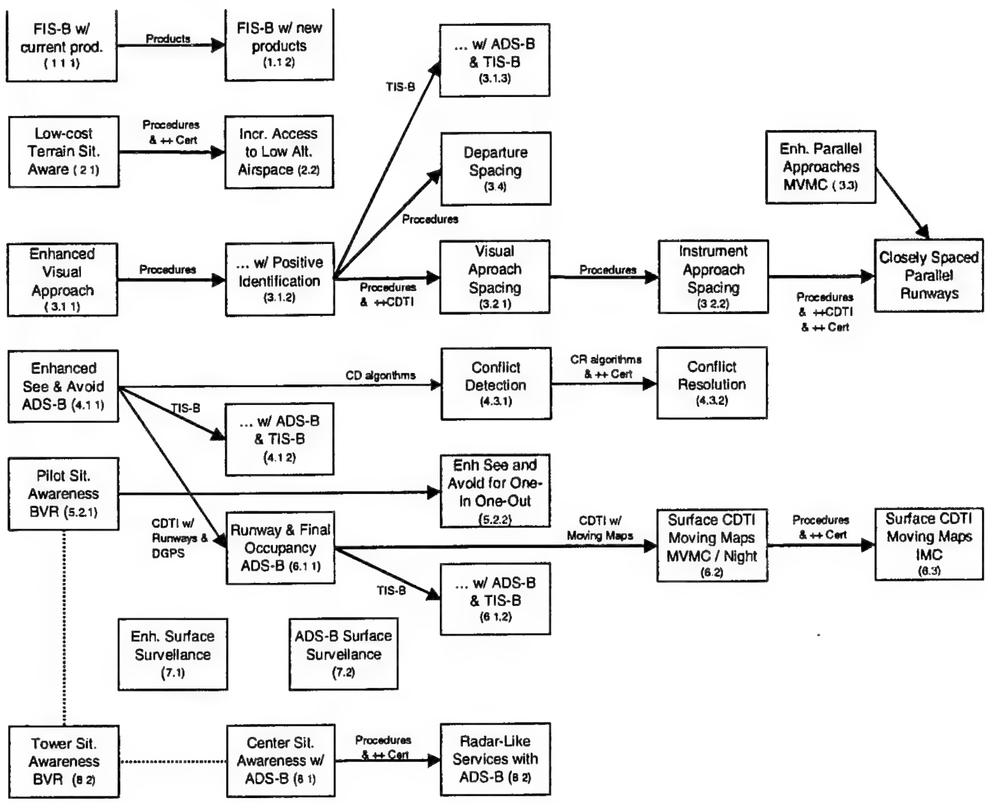


Figure 4-4. Application Dependencies

Technology Adoption and Benefits

The market penetration of new technologies in non-aviation contexts has been studied and modeled, and appears to correspond well to the introduction of voluntary avionics such as GPS. Critical to successful market penetration is understanding and targeting of different classes of buyers who tend to adopt a new technology at different stages in its maturity. (See Appendix B.) Potential "buyers" of Safe Flight 21 technologies have not yet been classified in this way, but factors that will drive their decisions have been identified and used to predict the "market penetration" (implementation) time-frame of Safe Flight 21 applications. This evaluation was presented to the Safe Flight 21 Steering Group as potential guidance in

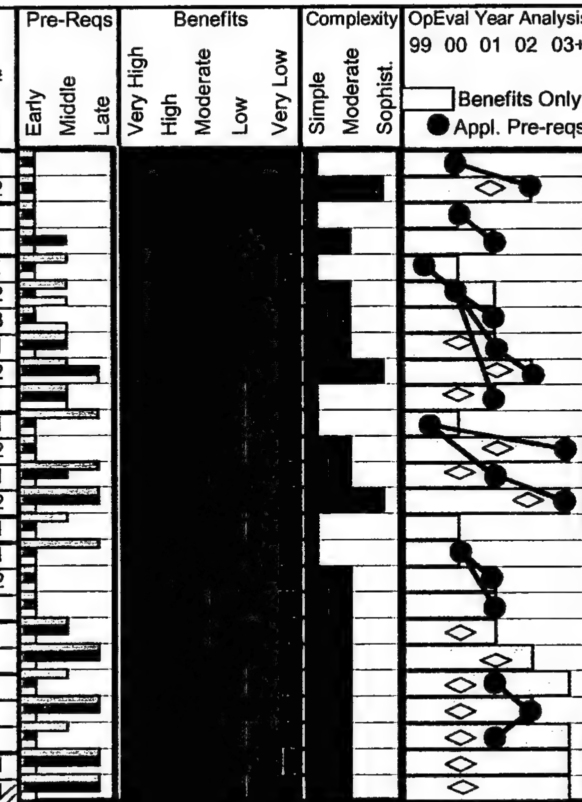
sequencing the development and evaluation of applications. The time frame for adopting a new capability depends on the pre-requisites for receiving benefits, the perceived magnitude of the benefits, and the complexity of making the capability available. Figure 4-5 illustrates this analysis, updated to reflect the current Safe Flight 21 applications.

The first graphic-column in Figure 4-5 evaluates **three pre-requisites**. The upper bar for each application shows the level of **equipage** needed for the buyer to obtain benefits. "Early" ratings indicate that no other aircraft need be equipped for the buyer to gain benefits. "Middle indicates that benefits are gained when a significant fraction of local aircraft are equipped, and is often associated with "pair-wise" operations between two equipped aircraft. "Late" indicates that substantial benefit depends on nearly all local aircraft being equipped (during the times of operation). The second bar for each application indicates the level of **confidence** in the new systems and procedures that is needed for them to be acceptable: early for advisory only, middle to extend or enhance existing essential systems, late for new systems essential to the safety of the new operations. The lower bar for each application characterizes changes to pilot/controller **procedures**: early for no significant change, middle for new or revised procedures, late for changes in roles and responsibilities.

The second graphic-column characterizes the magnitude or **importance of the benefits** to the buyer. Note that higher benefits are shown toward the left, corresponding to pressure for earlier adoption. (The dark left-side background can be viewed as patience for later adoption – extending to the right.) The third graphic-column describes the **complexity** of the systems and procedures that need to be developed, with greater complexity (to the right) pressing for longer development time.

The final graphic-column shows the results of combining these factors in the contexts of equipage by Capstone in the Y-K delta or cargo-hub operations at night. Within these contexts the local equipage at the times of operations will be high regardless of broader equipage levels. For this reason, the upper (equipage) bar in the pre-requisites column is factored out. Generation of the bar graph of OpEval years is table driven from the input assessment values without regard to technical, operational, or economic nuances. The bar graph also does not reflect development dependencies between applications (from Figure 4-4), or that two applications (3.1.1 and 4.1.1) were evaluated in FY'99 prior to this analysis. The dark dot-and-line overlays show these adjustments. The selected target dates for OpEval negotiated by the Safe Flight 21 Steering Group are shown (as light diamonds) where they differ from these. The right-most column lists the dates and locations that were selected.

Enhancement	Application (Sub Application)	ID#	OpEval Target Year Selected
Wx and Other Info to the Cockpit	Initial FIS-B based on todays availability	1.1.1	00 (AK)
	NOTAMs, lightning, icing, turb., r/t SUA, Volc. Ash	1.1.2	01 (AK)
Cost Effective CFIT Avoidance	Low cost terrain situational awareness	2.1	00 (AK)
	Increased access to . . . low altitude airspace	2.2	01 (AK)
Improved Terminal Operations in Low Visibility	Enhanced visual approaches (ADS-B only)	3.1.1	99 (ORV)
	. . . (w/ new procedures using ADS-B only)	3.1.2	00 (ORV)
	. . . (w/ new procedures using ADS-B and TIS-B)	3.1.3	01 (ORV)
	Approach spacing (for visual approach)	3.2.1	00 (ORV)
	. . . (for instrument approach)	3.2.2	01 (ORV)
	Departure spacing/clearance (VMC in radar)	3.4	00 (ORV)
Enhanced See and Avoid	Enhanced Vis Acq f/see-and-avoid (ADS-B only)	4.1.1	99 (ORV)
	. . . (ADS-B and TIS-B)	4.1.2	01 (Both)
	Conflict detection	4.2.1	00 (ORV)
	Conflict resolution	4.2.2	02 (ORV)
En Route Air-to-Air	Pilot situational awareness beyond visual range	5.2.1	00 (AK)
Improved Surface Surveillance and Navigation for the Pilot	Runway and final occup. awareness (ADS-B only)	6.1.1	00 (Both)
	. . . (using ADS-B and TIS-B)	6.1.2	01 (ORV)
	Airport surface situational awareness	6.2	01 (Both)
Enhanced Surface Surveillance /Controller	Surf. Surv. enhancements with ADS-B	7.1	00 (ORV)
	Surveillance coverage at airports w/o surf surv	7.2	01 (ORV)
ADS-B Surveillance in Non-radar Airspace	Center situational awareness w/ ADS-B	8.1	00 (AK)
	Radar-like services with ADS-B	8.2	00 (AK)
	Tower situational awareness beyond visual range	8.3	00 (AK)
Establish ADS-B Separation Standards	Radar augmentation w/ ADS-B (en route)	9.2.1	00 (Both)
	Radar augmentation w/ ADS-B (terminal)	9.1.1	00 (both)



= Prerequisite Local Equipage
= Prerequisite Confidence in New Systems and Operations
= Prerequisite Changes in Procedures or Roles

Figure 4-5. Analysis of Application Sequencing Based on Benefits

4.1.2.2 Prioritization

The results of the analyses outlined in Section 4.1.2.1 above were presented to the Safe Flight 21 Steering Group for consideration in their definition of an initial target schedule. The strawman sequencing of applications from the benefits/adoption analysis was used as a starting point.

The initial target schedule as derived from a voting process within the group which captured both the importance of the applications and the target timing for their operational evaluation. Next, the current status and operational evaluation target date for each application were reviewed together in light of the sequencing of applications in the schedule. Staff identified dates that appeared highly aggressive. Staff also analyzed the availability of resources for human-in-the-loop simulation and procedure development to identify likely conflicts between applications. After these analyses, the Safe Flight 21 Steering Group adopted an interim target schedule as a basis for further detailed discussion with participating stakeholders.

The achievability of any target schedule depends on the level of resources contributed by participating stakeholders and the FAA. Further, Safe Flight 21 is not pursuing applications for which no stakeholder has volunteered participation. Coordination with participating stakeholders resulted in adjustments to the target schedule that increased efforts on Approach Spacing and Surface Operations and on use of ADS-B for radar-like services in non-radar airspace. The result of these deliberations was a consensus between the Safe Flight 21 Steering Group and participating stakeholders on the target schedule and priorities for Safe Flight 21 applications. This was presented to the Free Flight Select Committee. In December 1999 the target schedule and priorities were reviewed and accepted by the Free Flight Steering Committee. This target schedule is presented in Section 4.2.

4.2 Safe Flight 21 Target Schedule

The Safe Flight 21 Steering Group, in coordination with participating stakeholders, has adopted a target schedule for evaluating and implementing the Safe Flight 21 applications within the nine operational enhancements. In each case, applications must progress from initial definition and development through an evaluation process that addresses feasibility, acceptability, and business case, into the stakeholder-driven stages of implementation.

This overall target schedule, organized by enhancements and applications, is shown in Figure 4-6 with the timeline at the right color-coded into Define & Development, Evaluation and Implementation stages. In terms of the tasks described in Appendix A, the **Define & Development** stage includes tasks 1 (Operational Concept), 3 (Maturity of Concepts & Technology), 4 (Operational Procedures), 5 (Human Factors Issues), 6 (End to End Performance and Technical Requirements), 7 (Interoperability Requirements), and 9 (Avionics and Ground Systems). The **Evaluation** stage includes 2 (Benefits and Constraints), 8 (Operational Safety Assessment), and 10 (Operational Test and Evaluation). The **Implementation** stage includes 11 (Equipment Certification), 12 (Operational Approval), which may have been completed earlier but will be complete by the first year, and 13 (Implementation Transition).

Recognizing that this is a target schedule and that resource constraints may necessitate delaying one or more of the applications, the steering group has also assigned an importance level to each of the application phases. The most important of these should be given priority and completed as quickly as possible. However, it is often the case that “less important” application or phase is a necessary stepping stone to completion of one more important. The current target schedule reflects these considerations.

Figure 4-6 also shows the location at which the operational evaluation should take place. Some applications will be evaluated at both locations. In this case, the first and primary location is shown in bold and the schedule reflects that location. The importance levels for each location (if different) are both shown in the same order as the locations, with the importance at the initial location in bold.

As noted in Section 4.1.1, identifying all of the complexities of the Safe Flight 21 applications and fully anticipating their resource and schedule requirements is an iterative process. Subsequent to the establishment of the target schedule by the Safe Flight 21 Steering Group in 1999, additional planning and initial results have become available. An adjusted target schedule that reflects this information is shown in Figure 4-7.

Target Schedule for SafeFlight 21 Applications

Define & Develop | Evaluate | Implement

#	Name (with development phase if needed)	Location	OpEval Year	Importance low 0 - 10 high	1999	2000	2001	2002	Beyond
1	**Weather and Other Information to the Cockpit**								
1.1.1	wx alerts)	AK	2000	9					
1.1.2	products)	AK	2001	9					
2	**Cost Effective CFIT Avoidance**								
2.1	Low cost terrain situational awareness	AK	2000	10					
2.2	Increased access to terrain constrained low altitude airspace	AK	2001	9					
3	**Improved Terminal Operations in Low Visibility**								
3.1.1	Enhanced visual approaches (exisiting procedures using ADS-B only)	ORV	1999	9					
3.1.2	Enhanced visual approaches (new procedures using ADS-B only)	ORV	2000	9					
3.1.3	Enhanced visual approaches (new procedures using ADS-B and TIS-B)	ORV	2000	6					
3.2.1	Approach spacing (visual approaches)	ORV	2000	9					
3.2.2	Approach spacing (instrument approaches)	ORV	2001	9					
3.4	Departure spacing/clearance (VMC in radar)	ORV	2000						
4	**Enhanced See and Avoid**								
4.1.1	Enhanced visual acquisition see-and-avoid (using ADS-B only)	ORV>AK	1999	7 / 9					
4.1.2	Enhanced visual acquisition see-and-avoid (using ADS-B and TIS-B)	ORV<AK	2001	6 / 9					
4.2.1	Conflict detection	ORV>AK	2000	10 / 8					
4.2.2	Conflict resolution	ORV	2002	10					
5	**Enhanced En Route Air-to-Air Operations**								
5.2.1	Pilot situational awareness beyond visual range	AK	2000	9					
6	**Improved Surface Surveillance and Navigation for the Pilot**								
6.1.1	Runway and final approach occupancy awareness (ADS-B only)	ORV>AK	2000	8					
6.1.2	Runway and final approach occupancy awareness (ADS-B and TIS-B)	ORV	2001	6					
6.2	Airport surface situational awareness	ORV>AK	2001	8					
7	**Enhanced Surface Surveillance for the Controller**								
7.1	Enhance exisiting surface surveillance with ADS-B	ORV	2000	8					
7.2	Surveillance coverage at airports without existing surface surveillance	ORV	2001	8					
8	**ADS-B Surveillance in Non-Radar Airspace**								
8.1	Center situational awareness with ADS-B	AK	2000	9					
8.2	Tower situational awareness beyond visual range	AK	2000	9					
8.3	Radar-like services with ADS-B	AK	2000	8					
9	**Establish ADS-B Separation Standards**								
9.1.1	Radar augmentation with ADS-B to support mixed equipage in terminal airspace	ORV>AK	2000	9					
9.2.1	Radar augmentation with ADS-B to support mixed equipage in en route airspace	ORV<AK	2000	9					

Define & Develop stage includes tasks in Appendix A: 1 (Operational Concept), 3 (Maturity of Concepts & Technology, 4 (Operational Procedures), 5 (Human Factors Issues), 6 (End-to-End Performance and Technical Requirements, 7 (Interoperability Requirements, and 9 (Avionics and Ground Systems)

Evaluation stage includes tasks 2 (Benefits and Constraints), 8 (Operational Safety Assessment), and 10 (Operational Test and Evaluation)

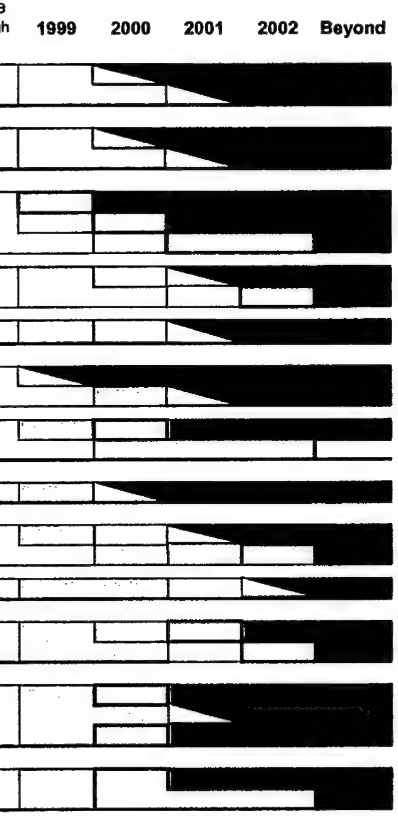
Implementation stage includes tasks 11 (Equipment Certification), 12 (Operational Approval), and 13 (Implementation Transition)

Figure 4-6. SafeFlight 21 Target Schedule

Target Schedule for SafeFlight 21 Applications

Define & Develop | Evaluate | Implement

#	Name (with development phase if needed)	Location	OpEval Year	Importance low 0 - 10 high
1	**Weather and Other Information to the Cockpit**			
1.1.1	wx alerts)	AK	2000	9
1.1.2	products)	AK	2001	9
2	**Cost Effective CFIT Avoidance**			
2.1	Low cost terrain situational awareness	AK	2000	10
2.2	Increased access to terrain-constrained low altitude airspace	AK	2001	9
3	**Improved Terminal Operations in Low Visibility**			
3.1.1	Enhanced visual approaches (existing procedures using ADS-B only)	ORV	1999	9
3.1.2	Enhanced visual approaches (new procedures, ADS-B only)	ORV	2000	9
3.1.3	Enhanced visual approaches (new procedures, ADS-B and TIS-B)	ORV	2000	6
3.2.1	Approach spacing (visual approaches)	ORV	2000	9
3.2.2	Approach spacing (instrument approaches)	ORV	2001	9
3.4	Departure spacing/clearance (VMC in radar)	ORV	2000	
4	**Enhanced See and Avoid**			
4.1.1	Enhanced visual acquisition see-and-avoid (using ADS-B only)	ORV>AK	1999	7 / 9
4.1.2	Enhanced visual acquisition see-and-avoid (using ADS-B and TIS-B)	ORV<AK	2001	6 / 9
4.2.1	Conflict detection	ORV>AK	2000	10 / 8
4.2.2	Conflict resolution	ORV	2002	10
5	**Enhanced En Route Air-to-Air Operations**			
5.2.1	Pilot situational awareness beyond visual range	AK	2000	9
6	**Improved Surface Surveillance and Navigation for the Pilot**			
6.1.1	Runway and final approach occupancy awareness (ADS-B only)	ORV>AK	2000	8
6.1.2	Runway and final approach occupancy awareness (ADS-B and TIS-B)	ORV	2001	6
6.2	Airport surface situational awareness	ORV>AK	2001	8
7	**Enhanced Surface Surveillance for the Controller**			
7.1	Enhance existing surface surveillance with ADS-B	ORV	2000	8
7.2	Surveillance coverage at airports without existing surface surveillance	ORV	2001	8
8	**ADS-B Surveillance in Non-Radar Airspace**			
8.1	Center situational awareness with ADS-B	AK	2000	9
8.2	Radar-like services with ADS-B	AK	2000	9
8.3	Tower situational awareness beyond visual range	AK	2000	8
9	**Establish ADS-B Separation Standards**			
9.1.1	Radar augmentation with ADS-B to support mixed equipage in terminal airspace	ORV>AK	2000	9
9.2.1	Radar augmentation with ADS-B to support mixed equipage in en route airspace	ORV<AK	2000	9



Slip in schedule

Define & Develop stage includes tasks in Appendix A: 1 (Operational Concept), 3 (Maturity of Concepts & Technology, 4 (Operational Procedures), 5 (Human Factors Issues), 6 (End-to-End Performance and Technical Requirements, 7 (Interoperability Requirements, and 9 (Avionics and Ground Systems)

Evaluation stage includes tasks 2 (Benefits and Constraints), 8 (Operational Safety Assessment), and 10 (Operational Test and Evaluation)

Implementation stage includes tasks 11 (Equipment Certification), 12 (Operational Approval), and 13 (Implementation Transition)

Figure 4-7. Safe Flight 21 Adjusted Target Schedule (reflecting current information)

Section 5

Program Analyses

This section highlights two of the important types of analysis that guide the Safe Flight 21 program. These include safety analysis and risk analysis. Subsequent versions of this Master Plan will also include summaries of work that is ongoing in human factors and benefits analysis and metrics.

5.1 Ensuring Safety

An important part of enabling certification of systems for advanced applications is to validate the overall level of safety that will result from their operational use. An operational safety assessment (OSA) of the Safe Flight 21 ADS-B applications (and potentially other ADS-B applications) has been begun under the leadership of FAA Certification (AIR) and Systems Engineering (ASD). Additional information, including the interface between Safe Flight 21 and the OSA, consistency of concepts of operation, and coordination with industry and users, will be addressed in subsequent versions of the Master Plan. The remainder of this section is preliminary, drawn primarily from processes developed to facilitate transition of controller/pilot data-link communications (CPDLC) and from the work of RTCA SC-189.

The CNS/ATM Safety Assessment extends from planning, through development, and operational use as depicted in Figure 5-1. It shows the (1) Operational Environment Definition (**OED**), (2) Operational Safety Assessment (**OSA**), (3) Institutional Safety Assessments (**ISA**s), (4) Development with embedded Development Assurance, (5) Continued Operational Safety (**COS**), and (6) Operational Use.

The **OSA** process identifies and classifies the hazards associated with the **OED** defined operational objectives and capabilities. An anomalous condition that occurs in a ground system may engender an operational hazard if it has an effect on the service being provided and thereby reduces the margin of safety of flight operations in a significant way. The Hazard Classification Matrix (**HCM**) is used to classify hazards by providing qualitative description of the effects of an identified hazard on operations, while a second matrix relates the hazard severity to estimated likelihood of occurrence. Each entry of severity level for a given likelihood of occurrence can be either acceptable, acceptable with review, acceptable with review/not acceptable with single point or common cause failures, or not acceptable as a level of risk.

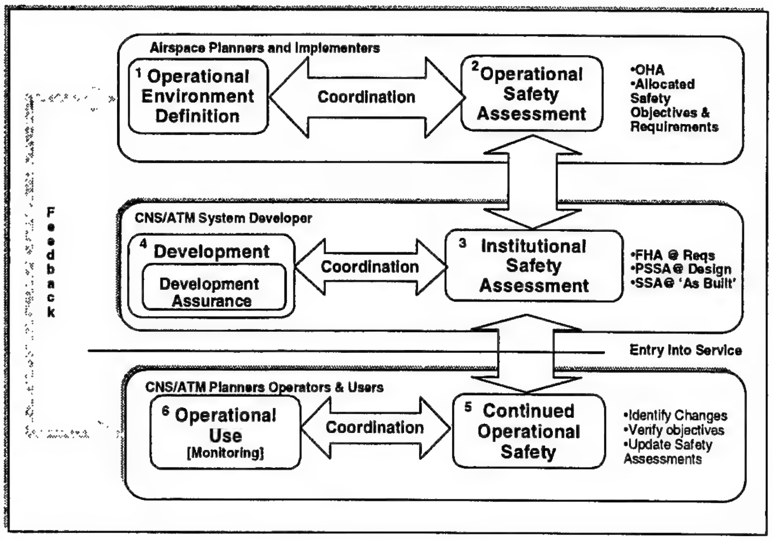


Figure 5-1. Overview of the CNS/ATM safety assessment process

The output of the **OSA** is a set of allocated safety objectives and requirements. The 'allocation' may be to any CNS/ATM system developer for aircraft, ground system, or support service system. A safety objective may take the form of required; functionality, function redundancy, architectural isolation, functional or system performance parameters, level of development assurance, target value for the probability of occurrence of a failure condition, operational procedures for aircrew, procedures for ground segment personnel, training, and/or, maintenance procedures.

Allocated safety objectives are given relative to a defined environment including a set of operational objectives to be implemented within an airspace that may include separation minima reduction objectives, procedural initiatives, and throughput goals in accordance with demand growth. The **OED** includes airspace characteristics, operations descriptive material, and functional characteristics required to circumscribe the hazards and their mitigation. **OED** and **OSA** processes proceed in parallel, and are updated when segment safety activities indicate the need. The ISA activities for each of the ground segment systems include:

- Tracing the safety objectives developed to those derived from the **OSA**
- Deriving any additional hazards, effects, and substantiation at the **ISA** level
- Identifying mitigation alternatives within institutional boundaries
- Allocating and validating safety requirements
- Ensuring application of the mitigation strategies

- Conducting ongoing risk mitigation and assessment reviews
- Coordination to provide information concerning hazards and mitigation to the **OED/OSA** and other segments coupled to it.

After development, qualification, and entry into service of a system, there is the continued need to ensure that environment changes, implemented as operations evolve, do not degrade the desired safety performance. **COS** includes monitoring the environment characteristics for changes that affect the safety of flight operations. The monitoring requirements are determined by analysis of the environment characteristics, documented in the **OED**. Change management, continued verification of mitigation means, configuration management, and organizational monitoring for continued coverage of safety objectives are also **COS** processes. For software components, problem reports are analyzed for the potential to induce operational hazards, and prioritized for corrective action accordingly. During operational use, we assure that the assumptions made in the OSA and used to formulate mitigation strategies are still valid.

5.2 Risk Management

In Safe Flight 21, as in any program, there are risks that can impact the successful completion of the program and implementation of the program's results. Risk management addresses and deals with program risks "up-front" before the risks adversely affect the program. Risk is the probability of an undesirable event occurring combined with the consequences of the occurrence. Thus, risk can be viewed as the probability that Safe Flight 21 will fail to deliver the benefits intended, either in whole or in part, and the consequence of this failure. Risks can derive from problems and uncertainties during design, development, implementation, or operation.

The basic steps in risk management are:

1. Identify potential risks
2. Analyze the risks as to their likelihood of occurrence and the consequences should they occur
3. Prioritize the risks based on the analysis as to which risks should be mitigated
4. Mitigate the risks by formulating and implementing mitigation actions
5. Track and control the program as to events that may trigger an adverse event, the status of the risks, and the status of mitigation actions.

These steps are shown in Figure 5-2.

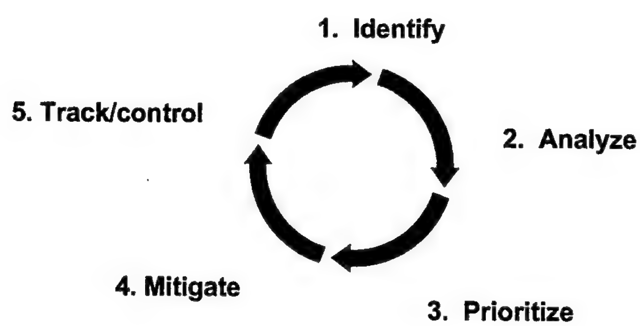


Figure 5-2. Safe Flight 21 Risk Management Approach

The Safe Flight 21 risks can be considered as long-term risks related to the deployment of Safe Flight 21 enhancements following the operational evaluations and as short-term risks related to successfully conducting the Safe Flight 21 operational evaluations, simulations, and other activities. The deployment risks relate to such factors as technology available to provide the desired functions, controller and pilot human factors affecting the usage of the

capabilities, acceptance by users (e.g., general aviation, cargo carriers, airlines, etc.) to purchase the necessary avionics, interoperability with existing NAS equipment, etc. The structure of the Safe Flight 21 program provides the opportunity to mitigate many deployment risks by addressing risk issues during the operational evaluations and simulations. Thus, risk management activities will identify and assess deployment risks so that they can be addressed during the operational evaluations and simulations. Safe Flight 21 program structure also involves aviation users; thus, potential risks involving users can also be addressed. The deployment risk assessment will also support the FAA Investment Analysis, which includes risk assessment and is part of the FAA Acquisition Management System to obtain FAA funding for ground infrastructure for Safe Flight 21 deployment.

The risk management process will be conducted continuously during Safe Flight 21. This will include updating the steps listed above as specific definitions of enhancements and applications are refined, as planning and conducting of operational evaluations and simulations evolve, and as the participants in Safe Flight 21 raise new issues. The continuous risk management activities combined with the operational evaluation and simulation activities provide the basis for the Evolutionary Spiral Process used in the Safe Flight 21 program to minimize modernization risks.

5.2.1 Risk Management Approach

The Safe Flight 21 Program Office is the focal point for risk management. The manager of each OpEval, application, or system will address risks that are entirely applicable to their portion of the effort. To maintain a clear picture of the overall risk to the Safe Flight 21 program, the program office will identify, analyze, track, and control all program risks. Where identified risks are crosscutting and affect more than one Safe Flight 21 activity, the program office will work with the affected managers to plan how and when the risk will be addressed. Some risks will be dealt with in the current cycle but for some, the most appropriate time will be in later cycles of the spiral. A Safe Flight 21 risk management process has been defined and is being implemented based on standard risk management techniques.

5.2.2 Risk Identification

There are a large number of issues concerning the operational evaluation and eventual deployment of Safe Flight capabilities. In general risks fall into six categories:

- Technical – Current technology does not support the required capability and/or the development of new technology is breaking new ground.
- Operational – Viable procedures have not been defined for the capability and/or those defined appear flawed.

- Acceptance – The capability involves sufficient uncertainty or departure from accepted practice that one or more required stakeholders may refuse to accept it.
- Benefit – The value of the capability to stakeholders is sufficiently uncertain that implementation decisions are not adequately informed.
- Cost – Current funding is insufficient to meet the needs of an activity
- Schedule – Current schedule does not allow sufficient time to meet Safe Flight 21 requirements

Risk identification extends to interdependent programs supporting Safe Flight 21. When a supporting program has risks, these risks must be assessed for impact on Safe Flight 21 technical, cost and schedule performance.

The Safe Flight 21 Program Office will ensure that all issues are screened for potential risk and that, once a risk is identified, it is maintained in a database of program risks to be addressed during the risk management process. Standard techniques and procedures will be developed to strengthen and standardize the Safe Flight 21 risk management approach including:

- Checklists
- Standard methods for assessment such as structured interviews
- Standard risk reporting forms
- Risk tracking database

5.2.3 Risk Analysis

Risk analysis is performed by analysts who assign probabilities and impacts to each risk. This determines the risk exposure to Safe Flight 21 from each risk. This is the first step toward prioritization.

5.2.4 Risk Planning and Prioritization

Once risks are evaluated and assigned exposure values, a series of discussions involving managers and stakeholders will be conducted to set the priority of all program risks and identify appropriate actions to reduce or mitigate the risks. These decisions will be documented in the risk database and, once a prioritized list of all Safe Flight 21 risks is developed, the candidates for mitigation will be identified. A risk plan will be developed that includes the mitigation action and its place in the current cycle or spiral.

Risks that require significant Safe Flight 21 resources or that significantly threaten stakeholder interests will be identified in the cycle plan in this Master Plan, and will be re-evaluated with the stakeholders each planning cycle.

5.2.5 Risk Mitigation

Risk mitigation includes actions that can reduce or eliminate risks. Possible actions include:

- Accepting the risk if the exposure is acceptable, the mitigation activity is very expensive, or it is completely outside of the control of the program
- Avoiding the risk e.g., avoiding development risk by using COTS
- Reducing the risk to an acceptable level through executing an action plan

These risk action plans will be recommended by the Safe Flight 21 Program Office or any stakeholder and executed by the appropriate organization. Risk triggers will be identified to indicate when action plans should be executed.

Stakeholders are an integral part of the risk mitigation approach and participate in quarterly program reviews at which risk mitigation status and progress will be reported and discussed.

Current risk mitigation approaches will be described in the risk management section of the cycle plan within this Master Plan, which will be updated each planning cycle.

5.2.6 Tracking and Control

The Safe Flight 21 Program will establish a tracking and control function as part of the risk management activity. Risks will be continuously monitored and reported and discussed with stakeholders as status changes. The initiation and completion of action plans will be monitored and reported in the Safe Flight 21 quarterly reviews and posted in the risk database.

5.2.7 Risks Identified

The next step in the risk management process will be for the Safe Flight program office and staff, along with other knowledgeable participants, to add, delete, clarify, and revise the risks, to assign ratings, and identify possible mitigation actions. This review will occur in structured interviews and workshops. Then, the risk assessments will be integrated, risks prioritized, and mitigation actions identified. Once this is completed, the risk mitigation actions will be assembled to support the planning on conducting of operation evaluations, committee activities (e.g., concept of operations and procedure development activities), and other appropriate Safe Flight 21 activities.

The following risk categories reflect deployment, or long term risks. Such risks are assessed as part of the Investment Analysis Process. In the case of Safe Flight 21, many of the deployment risks can and will be addressed during the Safe Flight 21 activities. The mitigation actions are actions that can be taken during the Safe Flight 21 activities to mitigate the implementation risks. The thirteen risk categories are:

- **$\text{Risk}_{\text{Technical}}$** is the risk associated with (1) developing a new or extending an existing technology to provide a greater level of performance than previously demonstrated, or (2) achieving an existing level of performance subject to new constraints. It also refers to how well the system operates to design or safety specifications.
- **$\text{Risk}_{\text{Operability}}$** is the risk associated with how well the system to be produced will operate within the National Airspace System (NAS) and interact with other systems. It addresses NAS or other system interfaces, the degree to which they are known and complete, and the degree to which the operational concept has been demonstrated and evolved to the point of a design baseline.
- **$\text{Risk}_{\text{Producibility}}$** is the risk associated with the capabilities to manufacture and produce the desired system.
- **$\text{Risk}_{\text{Supportability}}$** is the risk associated with fielding and maintaining the resulting systems.
- **$\text{Risk}_{\text{Benefit Estimate}}$** considers the difficulty in estimating the benefits. This risk facet addresses the accuracy of the benefit estimate, including such issues as inadequate methods to estimate the benefits, lack of data to estimate the benefits, whether the link of the alternative to projected benefits is tenuous, and whether the alternative is defined enough to estimate the benefits.
- **$\text{Risk}_{\text{Cost Estimate}}$** considers the difficulty in estimating the cost. This risk facet addresses the accuracy of the cost estimate, including such issues as inadequate methods to estimate the cost, lack of data to estimate the cost, and whether the alternative is defined enough to estimate the cost.
- **$\text{Risk}_{\text{Schedule}}$** considers the likelihood that the alternative will be completed within the specified schedule.
- **$\text{Risk}_{\text{Management}}$** refers to complexity of the alternative to manage (e.g., number of sub-tasks and/or number of performing organizations) and considers the risks of obtaining and using applicable resources and activities that may be outside of the alternative's control but can affect the alternative's outcome.
- **$\text{Risk}_{\text{Funding}}$** addresses the availability of funds when they are needed and a confidence in management and Congress that those funds will continue to be provided.
- **$\text{Risk}_{\text{Stakeholder}}$** is the risk associated with various stakeholders supporting the development and operation of the alternative, such as internal FAA organizational users, Congress, airline and general aviation users, and potential equipment and aircraft manufacturers.

- **Risk**$_{\textbf{Information Security}}$ addresses a system's vulnerability to external threats and the risks likely to occur in employing countermeasures.
- **Risk**$_{\textbf{Human Factors}}$ focuses on the effectiveness of the joint human-system interface and risks associated with making the system usable in an operating environment.
- **Risk**$_{\textbf{Safety}}$ considers the likelihood of system related hazards and the risks associated with preserving operational safety

Appendix A

Generic Tasks for Developing and Evaluating Applications

The generic tasks adapted from the RTCA planning guide[8] and mentioned in the body of this Master Plan are defined in Table A-1.

Table A-1. Generic Task Definitions

1 Operational Concept

1.1	Define Operational Concept	Safe Flight 21 program to provide technical and operational support to RTCA special committees and working groups defining operational concepts for some Safe Flight 21 applications. Product is extensions to the relevant operational concept documents (or new concept documents) needed to define operational roles and responsibilities, procedures.
1.2	System Functionality	Drawing on the Ops Concept, identify and characterize the systems and functionality required to support the application, and propose an initial functional decomposition that assigns functions to systems. Coordinate the proposed functionality and decomposition with the cognizant RTCA special committee. Incorporate these descriptions into a preliminary functional specification.

8 RTCA DO-249, *Development and Implementation Planning Guide for Automatic Dependent Surveillance (ADS-B) Applications*, October 1999.

2 Benefits & Constraints

2.1 Cost/Benefit Estimates and Parameters	Develop plans for operational analysis, performance metrics, data collection, and identify the tools and models necessary to analyze the application. Identify the constraints and parameters affecting the analysis and how these constraints and parameters should be characterized (through additional measurement and analysis) to more accurately estimate benefits as the application is further developed and evaluated. Perform high-level analysis of the costs and benefits of the application by estimating potential avionics and systems costs and by estimating potential benefit outcome metrics to service providers and users of the airspace system. Coordinate the analysis with metrics/benefits experts/organizations such as the C/AFT and AOPA. Estimates of potential benefit will be used by the Safe Flight 21 Steering Group in updating Safe Flight 21 applications priorities, and by the FAA in considering potential funding profiles for future implementation. The constraints and parameters that need to be characterized will be used in planning application development and evaluation activities.

2.2	Quantitative Costs and Benefits	Perform detailed investment analysis of costs and benefits, taking into account information on constraints and parameters that are quantified as the application is developed and evaluated. Estimate costs and benefit outcome metrics to service providers and users of the airspace system associated with local, regional, or national implementation. When critical parameters (such as equipage) are not yet characterized, analyze over a range of potential values. Coordinate the analysis with metrics/benefits experts/organizations such as the C/AFT and AOPA. The cost and benefit analyses for the application will be used to evaluate cases for implementing sets applications together. Results on critical parameter trade-offs may be used to plan subsequent refinement of the application.

2.3	Cumulative Implementation Cases	Analyze the distribution of benefits to different classes of NAS users, and to those who do or do not equip, if the application were implemented locally, regionally, and nationally. Considering the application *with* other applications, characterize the equipage decisions that will face different classes of NAS users, and in collaboration with users, characterize the likelihood and rate of equipage. From this, estimate costs and benefit outcome metrics to service providers and users of the airspace system associated with local, regional, or national implementation. Coordinate the analysis with metrics/benefits experts/organizations such as the C/AFT and AOPA. Implementation cases for sets of synergistic applications will be used by Safe Flight 21 to define and validate the capability of integrated avionics, ground systems, and procedures proposed for implementation. The case for a proposed implementation will be incorporated into decision making by the FAA, Users, and Industry.
2.4	Investment Decisions and Deployment Consensus	Summarize benefits, costs, implementation cases, and coordinate findings with joint FAA/User/Industry forum in preparation for investment decisions as required by the FAA Acquisition Management System and to support business decisions by Users and Industry.

3 Maturity of Concepts & Technology

3.1	Looks Feasible and Worth Developing?	In coordination with industry, user, and FAA organizations make decision that the application is feasible and worth developing for operational evaluation

4 Operational Procedures

4.1	Initial Definition of Procedures	Define procedures
4.2	Cockpit Simulation	Perform initial procedure evaluation using medium fidelity cockpit.
4.3	Controller Simulations	Perform initial procedure evaluation using appropriate level of ATC / controller simulation.
4.4	Procedure Parameters	Based on simulations (and analyses as needed), define preliminary limits to variable parameters the affect the acceptability and/or performance of the procedure. Examples of parameters include: visibility, separation between parallel runways, percentage of equipped aircraft in a controller's airspace, accuracy of acceptable CDTIs, inclusion of a velocity indicator on CDTIs.
4.5	Procedures Training	Define and formalize pilot and controller training and training materials.
4.6	Procedures Post-Full-Sim	Review and validation of procedures based on data from full-mission cockpit/ATC simulation.
4.7	Procedure Post-OpEval	Validate procedures based on data from operational evaluation

5 Human Factors Issues (Pilot, Controller, Other)

5.1 Task Analysis	Pilot/controller human factors task analysis. In coordination with SAE and RTCA, this contributes to standards definition needed for operational approval.
5.2 Initial Cockpit Human Factors	Cockpit human-factors evaluation and improvement as part of simulation for procedure development. In coordination with SAE and RTCA, this contributes to standards definition needed for operational approval.
5.3 Initial Controller Human Factors	Controller human-factors evaluation and improvement as part of ATC / controller simulation for procedure development. In coordination with SAE and RTCA, this contributes to standards definition needed for operational approval.
5.4 Human Factors Post-Full-Sim	Validate human factors acceptability based on data from full-mission simulation w/ high fidelity cockpit and ATC (required integration of ATC and cockpit simulations TBD)
5.5 Human Factors Post-OpEval	Validate human factors acceptability based on data from OpEval.

6 End to End Performance &Tech Reqs

6.1 Initial Performance Estimates	Drawing on knowledge of current prototypes, related systems, general engineering knowledge, and general operational knowledge, draft initial performance estimates for systems supporting the application.

6.2	Performance Requirements	Fast-time simulation and other analytic tools should be used to determine/ substantiate the data and performance requirements. In coordination with RTCA, this contributes to standards definition needed for certification. For example: RF performance analysis for aircraft-to-aircraft and air-to-ground (while aircraft are airborne and on the airport surface. A full-stress RF performance simulation to high equipage levels in dirty RF environment need to be performed to justify spectrum allocation/authorization.
6.3	Supportability Requirements	Define the approach to support and maintenance of systems supporting the application. Characterize the required support and maintenance functions and activities.
6.4	Performance Validation	Data should be collected throughout the simulations and operation flight evaluation to be used to validate the data and performance models. In coordination with RTCA, this contributes to standards definition needed for certification.

7 Interoperability Requirements for Air and Ground Systems

7.1	Interoperability Analysis	Perform a system interoperability analysis between various air-to-air and air-to-ground interfaces. In coordination with RTCA, this contributes to standards definition needed for certification.

7.2	Interface Requirements Documents	Based on specific functional and performance requirements, generate interface requirements documents. In coordination with RTCA, this contributes to standards definition needed for certification.
7.3	Interoperable Prototypes	Validate air-air, air-ground and ground-ground interoperability of systems and prototypes through simulation, laboratory testing, and off-line field-testing. In coordination with RTCA, this contributes to standards definition needed for certification.
7.4	Interoperability Post-OpEval	Validate interoperability based on data from operational evaluation.

8 Operational Safety Assessment

8.1	Rationale/Prelim Model	High-level safety rationale needs to be written for non-safety critical/non-hazardous applications. (1 month, 1 Staff Month)For safety critical applications develop a preliminary collision risk model and/or safety risk assessment prior to operational evaluation.
8.2	Validate Rationale/Preliminary Model	Data collected throughout simulations and operation flight evaluation are analyzed to feed/validate the safety assessment models.
8.3	Full Collision Risk Model	For safety critical applications develop a full collision risk model and/or safety risk assessment prior to implementation.

9 Avionics and Ground Systems

9.1 Systems and Avionics for OpEval	Develop or acquire ground systems and avionics as required to support operational evaluation of the Safe Flight 21 application(s) according to the functionality specified in the operational concept.
9.2 Systems and Avionics Certification and Approval	Develop or acquire ground systems and avionics as required to support avionics certification and operational approval of the Safe Flight 21 application(s) according to the functionality required for the defined operational procedures
10 Operational Test and Evaluation	
10.1 Limited Data Collection	Plan for and gather data during field testing, or in the targeted OpEval of another application, that assists in defining, evaluating, or partially validating an application or parts of an application.
10.2 Full Mission Simulation	Plan and conduct full mission pilot and ATC simulation.
10.3 Plans for OpEval	Through analysis and coordination, develop detailed plans for operational evaluations. Includes: test and evaluation program restrictions, defined success criteria, knowledge and procedures training, and policies on participation and access to data by organizations.
10.4 Operational Test and Evaluation	Targeted operational test and evaluation to validate the application as a precursor to operational approval and avionics certification.

11 Equipment Certification (Aircraft and Ground Systems)

11.1	Develop a Certification Issues Paper	
11.2	Develop Certification Plan	Certification plan (for Safe Flight 21 sponsored avionics.)

12 Operational Approval (Flight Standards and Air Traffic)

12.1	Develop Issues and Resolutions Document	Issues and resolutions document / documentation to support approvals.
12.2	Document Operational Regulations	Develop documentation on the operational regulations involved including current enabling regulations and new required regulations
12.3	Document the Human Factors Design Criteria and Guidelines	Enabling human factors design criteria and guidelines (I/O).
12.4	Document Air Carrier Approvals and Authorizations	Air carrier operator approvals and authorizations for flight crews, dispatch, and maintenance (avionics).
12.5	Document Approved Operational Data	Approved operational data including Minimum Equipment List (MEL).
12.6	Produce Approved Training Program Module	Approved training program module
12.7	Develop Operations Manuals	Operations manuals including General Operations Manual (GOM), Flight Operations Manual (FOM), Aircraft Flight Manual (AFM) and AFM Supplement as appropriate.
12.8	Develop Operational Specification	Operational specifications / authorizations.

12.9	Develop General Aviation Guidance Material	General aviation guidance material including advisory circulars, FAA handbook order changes, equipment usage and flight training, and pilot judgment training requirements.
12.10	Document Validation and Proving Runs	Validation / proving runs (air carrier and perhaps GA).
12.11	Document Post Operational Approval/Certification Activities	Post operational approval / certification activities including continued airworthiness (e.g., dispatch / MEL issues, need for periodic inspections).

13 Implementation Transition

13.1	Procedures In Service	Implement the procedure and evaluate it in actual use. (In many cases, this may be done incrementally as the limits for the accepted procedure are gradually extended.)
13.2	Benefits in Service	Evaluate the benefits of the procedure in actual use. (In many cases, this may be done incrementally as the limits for the accepted procedure are gradually extended.) .
13.3	Human Factors In Service	Validate human factors acceptability based on data from air and ground systems and procedures in actual use. (In many cases, this may be done incrementally as the limits for the accepted procedures are gradually extended.)
13.4	Performance In Service	Validate data and performance acceptability based on data from in service evaluation.
13.5	Interoperability In Service	Validate interoperability based on data from in service evaluation.

Appendix B

New Technology Adoption Model

There are several considerations for planning Safe Flight 21 operational enhancements. One of these is called the "New Technology Adoption Model" which prescribes characteristic consumer market behavior when new technologies are introduced to such markets. A desirable trait of this viewpoint is that it identifies the market forces that result in voluntary decisions to purchase equipment and use it in operations. These forces can be leveraged to accomplish a quick, efficient transition path to new, advanced operational capabilities, as has been demonstrated many times in high-tech industries.

Another consideration is the stated needs and preferences of the users and the FAA. These needs can be characterized in many ways, but one way of looking at them is the size of the problem the needs reflect, and how much relief or benefit could be realized by their resolution.

A third additional consideration at this point is the maturity of technologies and procedures. This is a very practical consideration of what is "do-able" given the nature of proposed procedural change, or operational use of new technology. It is consistent with the Evolutionary Spiral Process (ESP) model that endorses a step-at-a-time approach to technology and procedure development. It is also consistent with the likely ramp-up in numbers of users who become equipped and trained to perform new procedures.

As planning for Safe Flight 21 operational enhancements continues, it is probable that other factors may also be identified, and these can be readily incorporated. Therefore, it is useful to proceed with an analysis based on the factors identified above after a brief description is provided in the following pages.

The Technology Adoption Life Cycle (adapted from Moore[9]) provides useful insights on how new technologies and procedures are likely to be embraced by the NAS user community. Basically, if one plots the number of units of a "new technology" product purchased across a timeline, the result usually resembles a bell curve (see Figure B-1). This type of curve is applicable only to new technologies which require a substantial change in user behavior for benefits to be realized. Recent examples in consumer markets include palm-sized computer devices, cellular telephones, and VCR/camcorders - which all require, for example, that users invest time and money in equipment and training before they can see results. This is contrasted with other new introductions to the marketplace which represent

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9 Moore, G. A., *Crossing the Chasm: Marketing and Selling High-Tech Products to Mainstream Customers*, 1991, HarperBusiness, New York

only a slight incremental improvement to an existing feature - such as a new film for standard 35mm cameras which requires virtually no change in behavior to reap the small incremental benefit. The general technology adoption life cycle, therefore, applies only to significant new technology that requires substantial change in user behavior.

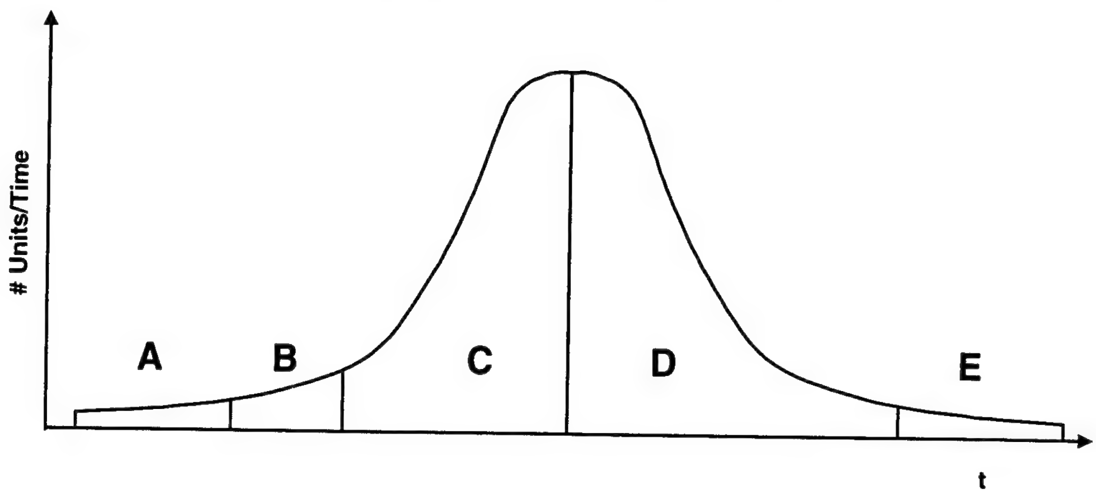

Figure B-1. New Products Purchased As a Function of Time

What high-tech market researchers have discovered is that, usually, a set of shared distinguishing traits will accurately characterize consumers in various parts of the bell curve. The curve can be broken down under the general titles of (A) innovators, (B) early adopters, (C) early majority, (D) later majority, and (E) those who never consciously join. These groups will be described in the general sense first, and then modified slightly for application to the analysis of Safe Flight 21 operational enhancements.

Leading the introduction of new technologies is the market-segment called the "Innovators". This segment is generally comprised of individuals who tend to embrace technology for technology's sake, without necessarily having any beneficial application in mind. There are a host of motivations which may prompt such fascination, but return-on-investment is not usually a significant criteria.

Following innovators is a group called the "early adopters", who tend to see how specific applications of new technology may benefit their operation. They are willing to invest time and effort to develop such applications from scratch, and are not overly concerned by the lack of standards or maturity.

The early majority group is practically-minded, and tends to embrace new technology once it has taken hold in the market, and development effort and risks are down. Those in this group tend to modify and extend applications pioneered by the early adopters into more mainstream areas.

The later majority is comprised of those who join the bandwagon when the cost of entry is suitably small. As used here, "cost of entry" is a broad term to include not only cost of equipment, but also training, maintenance, and other aspects of procurement and operation. A high-tech product has truly reached consumer status when it appeals to the later majority.

The last group consists of those who never consciously join the new technology's market, either for practical or philosophical reasons.

Several key principles have emerged in high-tech marketing in recent years. One is that the technology adoption life cycle is not really a continuum, but rather has breaks between the sub markets as shown in Figure B-2. This is due to the fact that the motivations people have for acquiring and using a high-tech product are usually very distinct, lending to crisply-defined market segments.

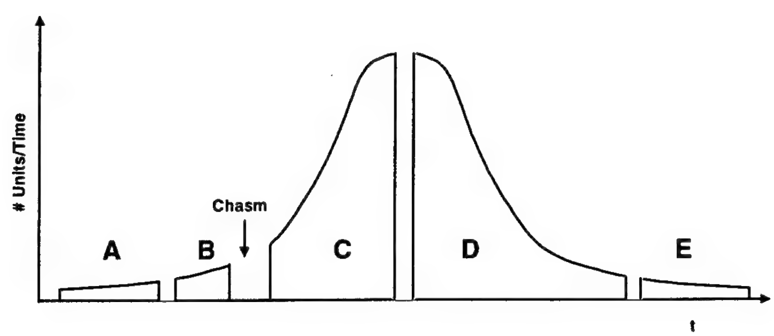

Figure B-2. The Chasm

A second key principle is that one needs a very specialized marketing plan tailored to the interests of each group. This is a natural consequence of the motivations and preferences unique to each group.

Finally, moving to the right, toward true "consumer status", requires that the new technology be effectively cultivated and marketed through all the segments to the left. The most common mistake in high-tech marketing is to attempt to jump into the majority regions of the curve, without a good foundation built by the experience and exposure provided by innovators and early adopters. A more effective strategy is to effectively market each of the identified groups (in sequence), and use the experience gained in one segment to serve as a launch point to the next.

A key focus of the work adapted for this discussion is that the most difficult marketing jump is from the early adopters to the early majority (the "chasm"). However, with proper treatment of the early adopter market, there are many ways in which this jump can be made more negotiable.

There are many ways in which this technology adoption model is applicable to the NAS and contemplated system upgrades - especially where user equipage is an issue.

First, when the cumulative number of units are expressed as a percentage of the total possible market, the equipage curve (on the right of Figure B-3) emerges. The two curves are directly linked, and the suggestion is that the desired, high user-equipage rates in the NAS will be best prompted by a well-considered, methodical "marketing strategy" that addresses each unique group. In addition, such a strategy will force resolution of the "chicken-egg" problems associated with such concepts as ADS-B (for which certain applications require high levels of equipage before benefits can be obtained). When considered in light of the model, it is possible to develop strategies for introducing ADS-B in ways that can effectively service the early adopters, thereby laying the foundation for jumping the chasm to more mainstream markets.

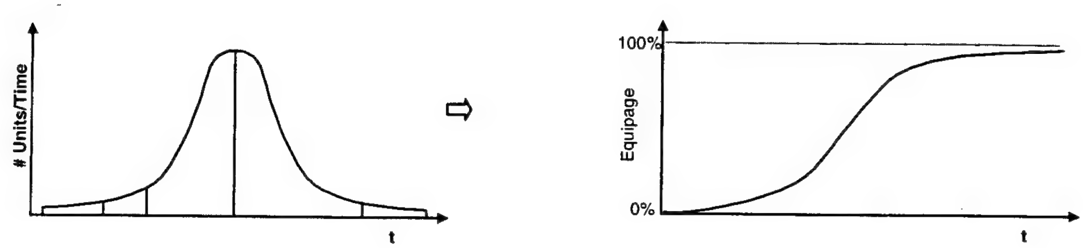

Figure B-3. Equipage

It also provides another valid basis for planning and sequencing Safe Flight 21 operational enhancements, and invites an ordered approach to gradually expanding the infrastructure and capabilities to support the market. It is not necessary to do everything at once, and such an approach is contrary to one of the most basic premises of effective high-tech marketing.

Finally, the model is consistent with other factors considered in the planning of Safe Flight 21 operational enhancements.

It should be noted that the user equipage curve drives many other curves reflecting the quality and effectiveness of future NAS operations. (See Figure B-4) The number of "advanced" operations, for example, is directly related to the percentage of users equipped to perform such operations.

Another dynamic related to the user equipage curve is the commensurate geographic region captured by gradually-increasing equipage levels. Innovators and early adopters in the NAS, for example, will likely equip for niche applications that are very local in nature. However, as more from the early majority join, the set of feasible operational enhancements grows toward regional and "universal" applications. (See Figure B-5)

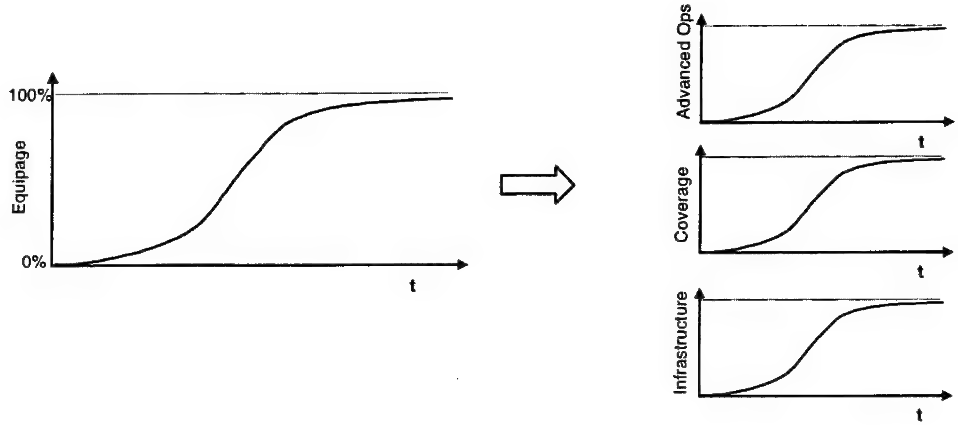

Figure B-4. Equipage Curve Feed Other Curves

Figure B-5. Geographic Implementation

For the sake of simplicity in applying the model to the Safe Flight 21 operational enhancement analysis, the five marketing regions have been conveniently gathered into three groups: "early" (consisting of A and B), "middle" (consisting of C and D), and "late" (E) as shown in Figure B-6.

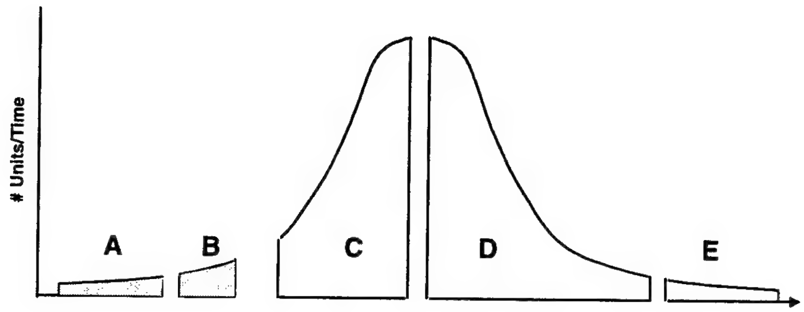

Figure B-6. Grouping the Regions

It is critically important that regions A and B be actively developed in order to make a successful jump to the majority regions, and many view this treatment of the early market to be the most important focus of the Safe Flight 21 effort.

As described earlier, participants in this market segment are drawn either by the novelty of the technology, or because it has the potential to provide benefits in focused applications. Participants are willing to invest resources necessary to get operational approval, and also to tolerate situations where standards may not exist and have to be developed. Generally, equipment purchases are made in quantities of ones or twos (or small lots) by individual or small fleet operators. The airlines participating in the Cargo Airline Association operational evaluation of ADS-B are characteristic examples.

The operational enhancements most appealing to the early segments are those which offer benefit on an individual basis (such as CFIT avoidance, FIS-B, and TIS-B) and do not require a high percentage of neighboring aircraft to be equipped. Another appeal would be to those fleet operators who could apply the technology (initially) where a high local concentration of "own" aircraft makes consideration of some ADS-B applications feasible.

Progression to the middle, majority regions of C and D can only happen if a good foundation has been laid in the earlier experiences of A and B. This is critically important for any NAS improvement.

Generally, applications in the majority markets are usually extensions of that which has been proven in the early markets. The early experience usually provides the basis for better and more comprehensive technical standards, and this gives the technology more credibility. This raises the comfort level for those in the mainstream who have been waiting to join. The comfort level is further raised as the technology gradually transforms into a stable consumer item, as evidenced by larger productions runs, simplified operation, and training. Far beyond a fad, technologies reaching the mature markets gain the status of being a "necessity".

Beyond the operational enhancements built up in the experiences of the early markets, the increasing equipage levels brought on by the majority regions enables more widespread use

of advanced air-to-air applications. This is because random pairings of aircraft over a large geographic region would likely produce two aircraft equipped to conduct such applications. Ultimately, at the very far right reaches of the majority portions, it might be safely concluded that, effectively, 100% of the NAS user-base is equipped. This would allow resource planners to consider scaling down redundant or back-up systems, depending on system availability and performance.

The final market group to consider consists of those who either do not want to join, or cannot join. There are many possible reasons but perhaps the most common are related to equipment limitations (e.g., no electrical system, or no weight/space allowance), or related to somewhat specialized missions to which the NAS "mass market" services are not usually responsive (e.g., crop dusting).

It may be that there will never be incentives for users in this region to equip. However, it is very helpful, even from the standpoint of better serving the majority markets, to closely examine this market segment. At the very least, methods of accommodation of this remnant should be examined.

Glossary

AAL	FAA Alaska Region
ACE	FAA Central Region
ACT	William J. Hughes Technical Center
ADS-B	Automatic Dependent Surveillance, Broadcast
AFM	Aircraft Flight Manual
AFS	Aviation Flight Standards Service
AIR	Aircraft Certification Service
AIRMET	Airmen's Meteorological Information
AK	Alaska
ALPA	Air Line Pilots Association
AMS	Acquisition Management System
AND	Office of Communication, Navigation, and Surveillance Systems
ANI	NAS Implementation
AOPA	Aircraft Owners and Pilots' Association
ARR	Requirements Development Directorate
ARW	Aviation Weather Program Directorate
ASD	Office of System Architecture and Investment Analysis
ASDE	Airport Surface Detection Equipment
ASR	Spectrum Policy and Management
ATC	Air Traffic Control
ATIDS	Airport Surface Target Identification System
ATM	Air Traffic Management
ATO	Air Traffic Strategic Operations Division
ATP	Air Traffic Procedures
ATS	Air Traffic Service
AUA	Office of Air Traffic Systems Development
AVR	FAA Regulation and Certification Group
C/AFT	CNS/ATM Focus Team
C/BSG	Cost Benefit Subgroup
CAA	Cargo Airline Association
CAA	Civil Aviation Authority
CAASD	Center for Advanced Aviation System Development
CDTI	Cockpit Display of Traffic Information
CD&R	Conflict Detection & Resolution
CFIT	Controlled Flight Into Terrain
CIP	Capital Investment Plan
CNS	Communication, Navigation, Surveillance
COG	Capstone Operations Group
CONOPS	Concept of Operations
COS	Continued Operational Safety

COTS	Commercial Off-the-Shelf
CPDLC	Controller/Pilot Data Link Communications
DFW	Dallas-Ft. Worth International Airport
DOD	Department of Defense
DOT	Department of Transportation
ECAS	Enhanced Collision Avoidance System
ESP	Evolutionary Spiral Process
EUROCAE	European Organization for Civil Aviation Equipment
FAA	Federal Aviation Administration
FFSC	Free Flight Steering Committee
FIS	Flight Information Service
FIS-B	Flight Information Service, Broadcast
FOM	Flight Operations Manual
FY	Fiscal Year
GA	General Aviation
GOM	General Operations Manual
GPS	Global Positioning System
HCM	Hazard Classification Matrix
I/O	Input/Output
ID	Identifier
IFR	Instrument Flight Rules
ILN	Wilmington, Ohio
IMC	Instrument Meteorological Conditions
IPT	Integrated Product Team
ISA	Institutional Safety Assessment
ISD	
JHU/APL	Johns Hopkins University/Applied Physics Laboratory
JRC	Joint Resources Council
LAAS	Local Area Augmentation System
MASPS	Minimum Aviation System Performance Standards
MEL	Minimum Equipment List
METAR	Meteorological Aviation Report
MIT/LL	Massachusetts Institute of Technology/Lincoln Labs
MNS	Mission Need Statement
MOPS	Minimum Operational Performance Standard
MP	Master Plan
MSAW	Minimum Safe Altitude Warning
MVMC	Marginal Visual Meteorological Conditions
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NATCA	National Air Traffic Controller's Association
NEXRAD	Next Generation Weather Radar
NMTF	NAS Modernization Task Force

NOTAM	Notice(s) to Airmen
NTSB	National Transportation Safety Board
O/PSG	Ops/Procedures SubGroup
OCG	Evaluation Coordination Group
OED	Operational Environment Definition
ORV	Ohio River Valley
OSA	Operational Safety Assessment
P&S	Performance and Standards
PIREP	Pilot Report
RD	Research and Development
RF	Radio Frequency
RTCA	RTCA, Inc. (formerly Requirements & Technical Concepts for Aviation; and formerly Radio Technical Commission for Aeronautics)
RTI	Research Triangle Institute
SAE	Society of Automotive Engineers
SC	Special Committee
SETA	Systems Engineering and Technical Analysis (supporting FAA)
SFStG	Safe Flight 21 Steering Group
SF21	Safe Flight 21
SIGMET	Significant Meteorological Information
SPECI	Unscheduled Surface Meteorological Data Report
SUA	Special Use Airspace
SVFR	Special Visual Flight Rules
T/CSG	Tech/Cert Subgroup
TAF	Terminal Area Forecast
TBD	To Be Determined
TCAS	Traffic Alert and Collision Avoidance System
TEMP	Test and Evaluation Master Plan
TIS-B	Traffic Information Service, Broadcast mode
TRACON	Terminal Radar Approach Control
TSO	Technical Standard Order
UPS	United Parcel Service
UPSAT	United Parcel Service Aviation Technologies
VCR	Video Cassette Recorder
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
WAAS	Wide Area Augmentation System
WG	Working Group
Wx	Weather
Y-K	Yukon-Kuskokwim delta area
ZID	Indianapolis Center

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